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CONFIDENTIAL

INTERIM REPORT

IMPACT OF ELECTRICAL POWER GENERATION ON THE ENVIRONMENT

by the
Energy and Environment Subcommittee
of the Advisory Committee on Energy (ONTARIO)

FOREWORD

The information presented in this report was compiled and prepared by the following members of the Subcommittee, Energy and the Environment;

Dr. K.E. Tempelmeyer (Chairman)	Department of the Environment
Mr. E.W. Stobart	Department of the Environment
Mr. M. Wood	Department of the Environment
Mr. W.L. Dick	Ontario Water Resources Commission
Dr. M.D. Palmer	Ontario Water Resources Commission
Mr. H.A. Clarke	Ontario Water Resources Commission
Mr. O.F. Hess	Department of Natural Resources
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Mr. J. Beaulieu	Task Force Hydro
Mr. B. Kelly	Pollution Probe
Mr. W.P. Corking	Consumers Association of Canada

Each of these committee members have drawn heavily upon colleagues in their organization for assistance in many forms and has contributed to the preparation of this report.

The recommendations of this report, if implemented would have a major impact on the supply of electrical energy to the Province of Ontario and on the overall environmental quality over the next twenty years. A representative from Ontario Hydro participated in all discussions and

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deliberations of this subcommittee and generously supplied all information requested. The conclusions and recommendations of this study however should not be interpreted as being endorsed by the Hydroelectric Power Commission of Ontario.

March, 1972

PREAMBLE

Increasing energy consumption is only one of a number of burgeoning demands that man places on his physical environment. Although the primary task of this subcommittee is to outline the environmental consequences of present and near-future energy consumption, it is deemed necessary to state explicitly that the long-range solution to environmental degradation rests with politcial, social and economic value changes which recognize the supremacy of the principles of nature and the need to live in harmony with them.

In historical terms we view our recommendations as delaying tactics to correct some known environmental degradations and to urge the adoption of a more conservationist strategy by government, business, and the general public in energy use. In so doing we recognize that for man to achieve a stable environmental harmony with nature, fundamental changes in policy and attitude toward consumption of all natural resources and the consequent degradation must take place.

The present task of reviewing the environmental effects associated with all aspects of the production and consumption of electricity has convinced this subcommittee of the need for the Ontario Government and the Hydroelectric Power Commission of Ontario to develop and implement more effective environmental policies and programmes designed not only to minimize the environmental effects of present activities but also to anticipate and regulate these activities in the future. Existing policies and programmes should be changed in recognition that (1) decreased en-

vironmental quality normally accompanies increased consumption, (2) improved pollution control and related technologies only provide short-term partial solutions, and (3) in the interim, consumers must expect to pay the full environmental costs of their electrical energy demands.

CONCLUSIONS

I General Implications of Electrical Power Generation

1. Electrical-power-generation organizations in North America, both public and private, have not fully recognized their responsibility in the past to safeguard the quality of the environment, because their charters or terms of references are primarily concerned with producing electricity at low cost, and with economic development. As a result, the price of electric power, like many other consumer goods, does not reflect its true cost to the general public. A variety of water-quality, air-quality and land-use effects give rise to real, but hidden costs to the public.
2. In the past five years power-generation companies have begun to recognize their environmental impacts and take measures to reduce them. However, the necessary technology is still not available to resolve many of the environmental problems of electrical power production. As a result, further environmental degradation will occur over the next decade and perhaps beyond due to the exponential growth in electrical production.
3. The existing degradation of environmental quality, due to energy use, is localized in extent, but will probably become more widespread with increasing urbanization of Ontario. The extent to which this trend may be overcome in the 1980's will depend upon the incentives, forced or induced, to produce "clean power".
4. The cost of pollution-control measures required for "clean power" will increase the price of electrical power in the future.

II Impact of Obtaining Fuels

1. Other countries and provinces will feel the need to implement control programmes on the industries which obtain and process fuel, in order to preserve the quality of their own environment. This will continue to increase the cost of fuel which Ontario purchases from outside the Province over the next two decades.
2. The Onakawana lignite deposit can be developed with an acceptable impact on the environment, provided that the proper precautions are taken. The sulfur content of the lignite on an equivalent energy basis is about 1 to 2%: therefore, sulfur abatement may still be necessary if it is used in an urban area as a solid fuel. Lignite gasification near the deposit with appropriate emission controls may be carried out in the long-term with an acceptable impact to the local environment. The gas produced would be an environmentally desirable fuel for Southern Ontario.
3. Detailed information on the ecology of the James Bay area is sparse. It is believed that the environment is much more fragile than Southern Ontario and careful studies are a prerequisite to large-scale development of the area.
4. Mining and milling of uranium has produced serious water-pollution problems in Ontario. Improved waste-handling techniques and control methods using existing technology are available and should be promoted. Emission of airborne radioactive substances can also be further reduced with improved practices.

III Impact of Processing and Transporting Fuels

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IV Impact of Generating Electrical Power

(a) Hydroelectric Power

1. Electrical power generation from falling water, produced by damming and diverting, has disrupted fish and aquatic populations, reduced aesthetic values and has occupied valuable land. Careful and complete ecological studies should be carried out prior to development of further water resources in Ontario.

(b) Fossil-Fuel Electric Power

1. Fossil-fuel generating plants, supplying the needs of a large urban area, represent a major contributor to poor or degraded air quality. Solid particulates are effectively controlled in Ontario, and the control equipment is now an accepted part of the generation equipment. Regulatory agencies are primarily concerned, at present, about the sulfur dioxide emissions from fossil-fuel plants. There is also increasing interest in future control of the oxides of nitrogen, as well as heavy metals.

2. Sulfur emission controls will be necessary in some generating stations to achieve the specified ambient SO_2 levels over the next two decades. Substituting low-sulfur fuel and mechanical or chemical coal cleaning offers little long-range potential for reducing sulfur emissions. Flue-gas desulfurization should be practical by the end of this decade and provide sufficient sulfur removal which together with the proper siting of plants will allow the ambient SO_2 air standards to be achieved through 1991. Flue-gas desulfurization will increase power costs by 5 to 10%. Coal gasification

appears to have the best long-range potential for reducing sulfur emissions. The United States has undertaken a significant effort to develop this process as a means of producing an environmentally clean fuel. The technology, if not the coal gas itself, may be exported to Ontario.

3. Natural gas is an environmentally desirable fuel. Its limited supply would appear to dictate that it be conservatively used, in applications where other sulfur abatement methods would be prohibitively expensive or not presently available.

4. Controls on the emissions of the oxides of nitrogen from power generation stations may be expected by the end of this decade. The necessity of controlling this air pollutant from power generation plants may be largely dictated by the success of the abatement programme underway for automotive sources. Reductions in these emissions up to perhaps 50% can be presently achieved, but technology is developing very slowly for the nearly complete removal of oxides of nitrogen.

5. Coal- and oil-fueled plants emit heavy metals and radioactive substances into the air due to impurities in fuel. At the present time, the concentration of these pollutants from fuel burning cannot be distinguished from the background ambient levels due to other sources. These substances may have significant health and environmental effects which could represent a potential long-range hazard.

6. Apart from waste-heat disposal, fossil-fuel plants impact water quality through the addition of slimicides and other chemicals to

the water, by drainage problems around coal storage piles and by minor oil spills. Also, wind-blown coal dust gives rise to air-quality problems. All of these problems should be manageable in the future.

(c) Nuclear Electric Power

1. The risk of a severe environmental impact due to a catastrophic failure at a nuclear power station is very small. It is not possible to weigh it in comparison to the long-term environmental effects of fossil-fuel plants.
2. The water and air radioactive emissions of nuclear plants on an annual basis are only 1 to 10% of the current allowable release limits. The present limits in effect provides a licence to pollute the air and water with radioactive wastes up to a certain point and expose the public to radiation needlessly. The nuclear industry and nuclear power plants should reduce and minimize all releases of radioactive contaminants to the fullest extent that is both technically and economically possible. The release limits should be immediately reduced to the lowest practicable levels.

(d) Disposal of Thermal Wastes

1. Both nuclear and fossil-fuel plants must dispose of up to 70% of their input energy as waste heat. At the present time, this is primarily achieved in Ontario by discharging heat into lake waters. The discharge of waste heat into the environment will increase proportionally to the increase in energy consumed by electrical power generation facilities.

2. Although the utilization of waste heat is highly desirable, the prospects of its beneficial use with existing plants is dim. Even for future power stations, a completely revised plant design concept would have to be integrated with a particular concept for waste-heat utilization. Cooling water would probably have to be discharged at higher temperatures and consequently the plant efficiency considerably reduced to find reasonable uses of waste heat. Moreover, the quantities of cooling water needed are tremendous, and there is concern that their use may alter circulatory patterns in some lake areas.

3. Up to the year 2000, significant increases of the temperatures of Lakes Ontario, Huron and Superior, due to the rejection of waste heat, may occur near the shoreline in the vicinity of once-through, water-cooled generating stations, particularly near the outflow from the stations. Shoreline regions however, are particularly important to the aquatic ecology. The future siting of plants, using once-through cooling, may alter certain desirable aspects of the aquatic environment up to 3 to 5 miles from the plant. However, in certain areas heating the water can provide beneficial effects by improving circulation patterns, and by increasing recreational potential.

   Addition of waste heat in the western and central basins of Lake Erie is undesirable. Several portions of Lake Erie already have serious water-quality problems which would be compounded by further heat addition. There is a possibility that the International Joint

Commission may recommend a restriction on waste-heat disposal and/or temperature rise in the waters of the Great Lakes. If Ontario accepts this, it would significantly affect present and future power stations located on the lakes.

5. Large evaporative wet cooling-towers appear to be an alternative to once-through cooling in Ontario. They are not expected to cause fog or ice problems except in their immediate vicinity, when unusual atmospheric conditions exist. A buffer zone around the station site would minimize the impact of this problem. The winter temperatures in Ontario could result in larger and persistent vapour plumes. The environmental impact of such plumes should be studied.

(e) Comparisons

1. The environmental impact of power plants whether nuclear, fossil-fuel or hydro is a matter of local and regional concern. It is not possible, at the present time, to adequately control all of their environmental problems by application of existing technology. Consequently, the conservation of electricity would reduce the growing degradation of our environmental quality. An advertising and price policy could discourage inefficient uses of electricity and assist in decreasing environmental degradation.
2. Hydroelectric plants cannot satisfy the future demand for power. Thermal plants using natural gas have a comparatively low environmental impact, but the limited supplies of natural gas preclude their use in the future except in special problem areas. Canadian natural gas reserves should be retained for Canadian use.

3. The basic choice for power generation which can supply the need at present is between (1) nuclear, (2) coal- or (3) oil-fuel plants. A CANDU nuclear plant appears to offer the lowest overall impact to the environment of these choices when all factors are compared. In some areas cooling towers could replace once-through cooling and produce a lesser overall impact on the environment.
4. It is difficult to compare the cost of continuing to generate electricity, as we have in the past, with the cost of environmentally clean energy. All of the needed information is not available or is impossible to assess for Ontario. However, as one example, in the U.S.A. it has been estimated that total cost to human health, vegetation, materials and property can be calculated at 10¢ per lb of SO_2 emitted. This cost is believed to be greater than authoritative estimates of the cost of flue-gas desulfurization.

V Impact on Land Use

1. There is increasing public concern about the "aesthetic impact" of transmission lines and tall stacks. There will be concern about the aesthetics of cooling towers. Public education and involvement of the needs and alternatives would increase the acceptance of stacks, towers and lines.

   Transmission line rights-of-way use land areas of about 100 acres per mile. Energy corridors (combined access of transmission lines, pipelines, rail lines) may make better overall use of the land, but are difficult to achieve. Inasmuch as fossil-fuel plants contribute greatly to urban air-quality degradation and all pollutant

emissions can not be adequately controlled, isolated power stations with the attendant price of longer transmission lines are the better environmental strategy provided that the transmission lines are planned for minimum impact.

3. In the past, the routing of transmission lines has consumed valuable woodland in Southern Ontario. Rights-of-way have adversely affected recreational, wildlife and historic areas. In some areas forest cover has also bee reduced below a desirable level. The clearing and maintenance of rights-of-way has produced several problems. Improved planning considering scenic and aesthetic values, wildlife habitat and multi-purpose uses is possible at this time.
4. Hydroelectric development has decreased the mileage of "wild rivers" in Ontario, altered aquatic life and migration, changed river beds and altered the surrounding landscape. Some water-power developments however, have been beneficial in providing additional recreational values in the areas involved. However, water-level fluctuations are detrimental to the values created.
5. The disposal of radioactive wastes, as well as chemical compounds formed in future flue-gas cleaning methods, will produce increasing problems in the future. Immediate attention should be given to the long-range radioactive disposal problems for Ontario, as well as to the legal implications of the Ontario responsibility for disposal.

VI Legal Aspects

1. Environmental legislation enacted by the Province of Ontario is the most extensive and comprehensive existing in Canada. The federal programme is just getting underway and its scope and impact can not yet be foreseen.

2. The United States has enacted or is considering several novel measures including (1) mandatory preparation of environmental impact statements that become part of the public record before a project or programme is undertaken, (2) taxing certain types of pollutant emissions or fuel additives, (3) setting maximum emission levels from fossil-fuel power generation stations and (4) establishing rules for power plant siting with public hearings.

VII <u>Environmental Quality - 1991</u>

1. In order to maintain reasonable air quality in Ontario to 1991, fossil-fuel plants should be sited no closer than 30 miles apart and at least 30 miles from the areas of (1) the Toronto region, (2) Hamilton, (3) Windsor, (4) Sarnia, (5) Sudbury and (6) other special areas until extensive pollutant control systems become available and are used.
2. The strategy of abatement and control of air and water pollutants is highly preferred over the strategy of dilution.
3. The water quality in the Great Lakes in the years to 1991 will largely depend upon the Canadian and American effort undertaken in accordance to the recommendations of the International Joint Commission.

VIII <u>Longer-Range Implications</u>

1. There are definite limits to exponential growth patterns which induce a stress on the environment, including the exponential growth of electrical power-generation capacity.

2. Modest climatic changes are now occurring in urban areas. This trend will continue and cover wider and wider areas. Global climate changes of major proportions are not likely by the end of this century but appear to be a distinct possibility in a hundred years or so.
3. A complex computer model of global dynamics by Jay Forrester predicts some disturbing consequences by the middle part of the next century in which the growth of the global society is limited by the depletion of natural resources or by a "pollution crisis". A stable global situation according to his model will only result by some form of a "zero growth" society. His model is based upon many assumptions which are currently being questioned and investigated; however, it is receiving world-wide attention.

RECOMMENDATIONS

An assessment of the environmental impact of electrical power generation has resulted in the following recommendations:

PART I Decision-Making and Regulation

It is believed that Ontario Hydro has begun to move in the direction to interact more strongly with Provincial Government Departments on environmental matters. Policy should be established and implemented to assure, (a) proper consideration of environmental problems, (b) more public involvement and (c) uniformity in energy policy as it impacts the environment.

1. Environmental Impact Statements

It is recommended that the Ontario Government establish a policy of requiring that Environmental Impact Statements be completed and evaluated before the implementation of any new programmes or projects which would significantly affect the environment. This requirement specificially recommended for Ontario Hydro, is also suggested for other projects and programmes, both public and private, which involve energy consumption and may have a significant impact on the environment. The statement should establish the need for the project, predict environmental consequences, and indicate the alternatives examined. The statement must play a real part in the decision-making process and should not be prepared merely to justify decisions already made. If requested, the ACE Energy and the Environment Subcommittee could undertake the design of this format at some future date.

2. Public Involvement

It is recommended that the fact-finding and decision-making processes for plant siting, environmental implications, production capacity, rate structure, transmission line rights-of-way, etc. be shared with the public. The Environmental Impact Statements and comments on them from government agencies should become public information and an official public hearing should be held where the public and citizen groups can express their views in an effective manner.

3. Continuity and Review

It is recommended that some mechanism be established whereby there is (a) a continuity and assessment of policy with regard to environmental protection and (b) a review process for existing plants and installations. The review process should take place when required at the option of the appropriate regulatory authority and may include the preparation of a modified form of Environmental Impact Statement and a public hearing.

4. The Role of Existing Regulatory Agencies

It is recommended that the existing regulatory agencies of the Provincial Government (principally the Departments of the Environment, Natural Resources, and Health) continue to establish the criteria for achieving and improving the quality of our environment in all respects. There is, however, a need to co-ordinate the activities and responsibilities of these agencies as they pertain to Ontario Hydro, especially in the area of establishing criteria for and evaluation of Environmental Impact Statements.

Ontario Hydro should work closely with these departments in:

(a) site pre-selection environmental studies

(b) ecological studies

(c) evaluation of abatement methods

(d) monitoring programmes

(e) all other programmes of common environmental interest.

Moreover, it is recommended that Ontario continue its efforts to establish multi-lateral criteria and control programmes with appropriate States to improve the environmental quality in international boundary regions.

5. Ontario Hydro's Environmental Role

Since the Commission is an agency of the Ontario government and the government's stated policy is to provide adequate energy supplies and to achieve a satisfactory environmental quality, the operation of Ontario Hydro should strongly implement both aspects of this policy.

(a) Consequently, it is recommended, that as a public commission, Hydro should not consider the environment a "free good" and in fact should lead the way in this important change in business attitude and operation. Increased electrical power generation will result in more widespread environmental degradation in the future. Recognizing and accounting for external diseconomies is an important first step towards improved environmental quality. It would also aid in resolving the basic conflict between power generation and environmental quality.

(b) It is recommended that advertising, marketing policies and rate structures be designed to encourage conservation of electrical energy by limiting the unnessary and inefficient demands

(b) ecological studies

(c) evaluation of abatement methods

(d) monitoring programmes

(e) all other programmes of common environmental interest.

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(b) It is recommended that advertising, marketing policies and rate structures be designed to encourage conservation of electrical energy by limiting the unnessary and inefficient demands

for electricity as long as the production of electrical power has a significant impact on the environment as it does now. A pricing policy for electrical power should also encourage the use of pollution abatement equipment by industry and municipalities thus shifting consumer preference away from products which use electricity inefficiently and therefore have a larger impact on environmental quality. The Commission should be judged not only on how efficiently and economically electrical power is produced, but also on how effective it is at minimizing its overall impact on the environment while supplying the basic electrical power needs of the Province.

PART II Implementation of Recommended Policies for Decision-Making and Regulation

It is recommended that a specific procedure or organization be identified to carry out the policies recommended above.

This might be achieved in a number of ways, but two specific suggestions are outlined below;

(1) The Minister of the Resource Development Policy Field or the Minister of the Department of the Environment should be responsible for implementing the administration and co-ordination of the Environmental Impact Statements, utilizing Ministers and personnel in various Departments in his Policy Field, as well as from other Policy Fields. He would request the preparation of Environmental Impact Statements for existing installations

when deemed necessary in consultation with other Ministers. After the Environmental Impact Statement is prepared by the submitting agency, it is circulated by the Minister or his designate to appropriate governmental agencies in all Policy Fields for comment and evaluation. He would also have the responsibility for establishing the required public hearings and he or his designate together with his staff and advisors would have the independent responsibility for reviewing and evaluating the Impact Statement and all comments (governmental and public), publishing their conclusions and reporting and advising the Policy and Priorities Board and the Provincial Cabinet on appropriate action. This method has the advantage of making use of the existing government framework.

(2) Alternatively, a broad-based energy regulatory board could be established by law to consider all aspects of energy use in Ontario and with the authority to approve and reject proposals. Consideration of environmental issues through the impact statements would only be one aspect of the board's activities. Other activities could include, reserve forecasting, resource developing, price structure, etc. It could be made up by appointment of specialists in many fields (engineering, economics, law, ecology, etc.) and representatives of the public. The board would (1) utilize experts in appropriate government agencies to assist in the evaluation of the environmental impact statements or other material, (2) hold public hearings on all aspects of energy use,

and (3) request additional studies if necessary. Positive decisions by the board to proceed would be referred to the Cabinet so that additional factors could be weighed before a final decision is reached. A negative decision of the board not to proceed for technical reasons would require no further action. This approach has the advantages that it considers environmental problems in a broader context and may fit into a broader policy recommendation.

(3) If judical public hearings are adopted, for the purpose of implementing the above or other approaches to increase public involvement, free legal council should be provided to the public.

PART III Recommended Research and Development Work

1. Expansion of the Commission's Environmental Programme

Ontario Hydro has an internal research and development programme in pollution control, supports work in other organizations and employs environmental consultants. Nevertheless, their programme is believed to be modest in comparison to what must be done to find near-future solutions to the pressing environmental problems associated with electrical power production. It is recommended that Ontario Hydro carry out or support and expanded in-depth research and development programme in those problem areas which are unique to Ontario by virtue of its geographical location and climate and which are attendant to power production by large energy generation centers being planned by the Commission. Some areas requiring research are (a) the effects of large onshore discharges of cooling water on lake currents and ecosystems, (b) analytical and experi-

mental investigation of the potential of icing and fogging from cooling towers and lagoons and investigations of the aerodynamic interference of the cooling tower on its discharge plume, (c) undertaking of conceptual studies of the beneficial uses of waste heat, and (d) investigation of optimum methods for providing electrical power.

The Commission already has research and development work underway in pollution control, but the problems are of sufficient importance that their existing programme should be increased several-fold. <u>It is recommended that additional environmental studies be carried out for (1) the investigation and research of environmental problems attendant to the generation and transmission of electrical power, (2) the conduct of ecological studies needed for plant siting or the development of new energy resources, (3) the development of pollution abatement equipment and systems for power stations, (4) the construction and evaluation of pilot-plant abatement systems and (5) the investigation of new ways to produce electrical energy for large-scale use.</u>

Several specific suggestions are made in the body of the report. An expanded investigation of the removal of sulfur dioxide and oxides of nitrogen from flue gases, the study of fluidized-bed combustors, the development of new transmission methods or underground cables are noteworthy among these. Because the Commission can not be expected to work extensively toward the solution of all environmental problems associated with electrical power production, the regulatory agencies could aid in establishing priorities so that necessary environmental quality goals may be achieved. Further, Ontario cannot afford to await for these problems to be solved elsewhere.

2. Development of Onakawana Lignite Deposits

The Northern Ontario environment is believed to be fragile with respect to environmental stress. If the Onakawana lignite deposits are developed, it is recommended that this development be strictly controlled to ensure a minimum environmental impact. In addition, Environmental Impact Statements are recommended for all energy developments such as this. Such development should be preceded by complete ecological and environmental studies.

The gasification of this lignite would ensure an environmentally desirable fuel for Ontario. Consequently, it is further recommended that an on-site lignite gasification plant be considered in the development of this resource, and that the research and development work needed to promote this development concept be undertaken.

PART IV Future Power Generation Systems

1. Generation Plants with Minimum Environmental Impact

Each type of generating plant produces a very different kind of impact on the environment. As a result, it is difficult to make meaningful comparisons. Nevertheless, it is believed that a nuclear plant using the CANDU system will produce a lower overall environmental impact than other contemporary power generation systems. Furthermore, it appears that natural-draft, evaporative-type cooling towers, particularly in conjunction with a nuclear plant, may provide a cooling method with lower environmental impact for some areas.

It is not possible to generalize and recommend a minimum impact power plant system for all locations. However, based on present technology and environmental considerations, nuclear plants are generally preferable

provided the following steps are also taken;

(a) Uranium mining practices recommended below are followed.

(b) The release limits of radioactive emissions into the water and air are reduced to the lowest practicable levels.

(c) Methods to dispose of radioactive wastes from an expanded nuclear power-generation industry in the next two decades are carefully investigated now.

In addition, pilot studies should be undertaken for Ontario conditions of the water-vapour plume from cooling towers.

The following guidelines are recommended;

(a) To improve air quality - the installation of future coal- or oil-fired palnts be avoided in the southern portion of the Toronto Centered Region and in any case large fossil-fuel power generation centers of 4000 MW and greater not be spaced less than 30 miles apart in other regions.

(b) To improve air quality - natural gas should be reserved for use where other emission control measures are not practical. Its use is not recommended for future generation stations where other control methods can be employed.

(c) To improve air quality - Ontario should strive to achieve a Canadian policy of retaining environmentally desirable natural gas for Canadian use.

(d) To improve water quality - once-through cooling not be allowed for future plants sited on the Western Basin of Lake Erie.

(e) To maintain water quality - in other areas where harmful effects can be predicted, alternative cooling facilities, which will not seriously impact the aquatic environment, should be employed. In those instances where potential harmful effects may exist, but cannot be clearly predicted, power plants should be initially designed so that alternate cooling facilities can be added at such time as evidence indicates significant adverse effects. Cooling water discharges should not alter local existing circulation patterns such that other water uses are seriously depreciated, or spawning and fishing grounds are affected.

2. Hydroelectric Plants

Ontario Hydro has paid approximately $45 million in the past five year in Water Power Rentals to the Province for the right to employ Crown Land in the production of hydroelectric power. It is recommended that a portion of the funds from Water Power Rentals in the future be made available for repairing the environmental damage caused by hydroelectric plants, to incease the fishery, to clean up headponds, to repair erosion and siltation damage and to create recreational multiple-use facilities.

In the future for development of hydroelectric plants, the following steps are recommended;

(a) Long-term studies are necessary to investigate future water needs and the potential consequences of major diversions. An Environmental Impact Statement be required for the

development of future hydroelectric power developments. It may include or specify the completion of an ecological study of the region.

(b) Land should be purchased and managed for public access, boat-launching, shore fishing and other facilities within the reservoir and upstream, and when practical, reservoir levels should be maintained for optimal recreational benefits.

(c) Flows should be maintained to ensure upstream migrations and spawning and culture of fish in downstream waters. When spawning habitat is lost, stocking and spawning channels be provided.

(d) Water quality should be maintained during construction and clear-cutting to above floodwaters and removal of timber should be made in every reservoir to accepted standards.

(e) The losses and impact to Indian bands, whose heritage and way-of-life depend upon the waters, be minimized.

(f) The overburden from stream diversion or deepening should be transferred to depressions or diked areas.

PART V <u>Broad-base Policy</u>

1. <u>Control of Radioactive Releases</u>

<u>It is recommended that future extraction of uranium ores take place with adequate environmental protection. The following steps are necessary for the protection of environmental quality in the mining areas;</u>

(a) Stablization and maintenance of all abandoned tailings areas to secure, in perpetuity, their containment including isola-

tion and cover, and erosion control. Collection and treatment of seepage and runoff should be provided by the mining companies or their successors responsible for the disposal sites. Provincial legislation dealing with stablization of tailings areas by vegetation or other methods should be extended to include abandoned areas and, as required, treatment of seepage and runoff.

(b) Mining companies should pursue the use of improved process and waste treatment techniques such as sulfide removal. Priority should also be given to the control of pH and toxic compounds such as heavy metals and ammonia.

(c) Use of lake basins for containment of tailings at new mining locations should be prohibited.

(d) Further studies are needed to examine the total human intake of radioactivity through air, food and water in those areas where waters containing significant quantities of radionuclides are used for domestic water supply. It is expected that the radiation dose resulting from short-term use of these supplies may not present a significant hazard to health; however, it would be advisable to consider alternate supplies since any unnecessary exposure to radioactivity should be avoided.

In view of the growing consumption of energy and the existence of other environmental forces directing us toward the installation of ever-increasing nuclear power capacity, it is recommended that the following

policies be adopted;

(a) Radioactivity in the aquatic and atmospheric environments attributable to controlled releases from all operations should be kept to the lowest practicable level.

(b) All release levels should be carefully reviewed periodically and revised so that the build-up of long-lived radioactivity in the environment should not unwittingly become a legacy for future generations.

(c) From an environmental viewpoint the use of breeder reactors should be discouraged in Ontario. Further, the environmental impact of fuel-reprocessing plants and uranium-enrichment plants should be carefully evaluated and very low radioactive release levels established before they are allowed to operate in Ontario.

(d) The total amount of radioactivity in the sediments, water and biota of the Great Lakes should not be allowed to increase by the discharges from future nuclear power plants.

(e) Contingency plans to cover mass evacuation from nearby populated areas in the event of (a) leakage from a nearby nuclear generating station or (b) from a heavy water plant, be periodically reviewed as population trends change over the next two decades.

2. <u>Contingency Planning for Fuel Spills</u>

To minimize the adverse effects which would almost certainly result from a major spill of fuel oil or other hazardous materials, <u>it is recommended that contingency planning activities receive a high priority within the</u>

Ontario Government and that an effective response capability be developed.

3. Land Use Planning

It is recommended that the Ontario government promote (where consistent with reliability of service) the concept of "the energy corridor", grouping transmission lines, pipelines, transportation lines together, thereby reducing the amount of land needed for utility easements. By having multi-utility easements planned in such a manner, the corridors can offer additional and needed recreational areas and also can provide rapid-transit rights-of-way in urban areas. The following recommendations are made with respect to transmission line routing and procedures:

(a) Develop techniques directed toward the future replacement of major transmission lines with underground cables in some areas.

(b) Intensify studies on multiple use and utilize rights-of-way for recreational purposes. Accelerate studies on how to obtain additional multiple use values from transmission lines by establishing and maintaining low cover for wildlife habitat and food.

(c) Route transmission line corridors to minimize destruction of valuable woodlands and to avoid special interest areas of ecological and/or historic significance.

(d) Intensify studies to maintain or improve the aesthetic values of power generating installations and field operations by sculpturing, visual screening, etc. Where feasible, replace lines over water by submarine cables.

(e) Locate large energy centers to avoid conflict with designated wilderness areas and "wild" rivers.

4. Solid Waste Disposal

(a) Investigations should be initiated to determine the overall impact of the disposal of radioactive wastes as well as chemical compounds formed as a result of future flue gas cleaning methods.

(b) A study should be undertaken to determine if Ontario may have any long-range problem in the disposal of nuclear wastes and whether the present division of responsibility for control of the disposal of such waste with the Federal Government will be adequate in the future.

5. Long-Range Implications

Ontario Hydro together with other agencies of the provincial government should assume the responsibility for very long-range studies of the consequences of exponential growth, energy consumption and electrical power generation. The conflict between our way-of-life and the environment is no sharper than in the consumption of energy resources. These long-range trends should be forecast and shared with the public.

Section I

INTRODUCTION

In North America and elsewhere in the industrialized world we have placed a high priority on convenience and consumer goods. The conflicts between consumption patterns, the growth which many people appear to want and the environmental insult which we all would like to avoid is, perhaps, sharper for the consumption of energy than for any other resource. Everyone wants to use as much electricity as he needs, whenever he wants it, to power a wide variety of gadgets, yet, few people like the sight of a power plant with its discharges into the environment or its transmission lines. Similarly, nearly everyone desires an automobile or two for his own transportation, yet no one consciously wishes to contribute to air pollution or traffic congestion. Because of the growing opposition in North America to the location of power plants and opposition to the expansion of freeway systems in our urban areas, it must be concluded that, for an increasing number of people, these services are no long acceptable, under the terms offered. The general public is becoming aware of the hidden costs of degrading the environment.

The use or conversion of energy completely pervades our daily lives and at the same time poses almost every type of environmental problem we face. There is probably no more important single area for which environmental protection and long-range planning should be emphasized than in the use of our energy resources. Although it is not possible to eliminate all environmental effects from energy use, it is practical to minimize these effects by long-range planning, selective siting, careful design and con-

struction, optimizing operating practices and incorporating new technology as it evolves.

Until quite recently the selection of fuel for any use was only a matter of choosing one with the lowest apparent cost. Our rising environmental concerns have altered the traditional concept of what is desirable. Today, selecting a fuel involves considering the effects on the air, water and land of (1) obtaining it, (2) processing and transporting it and (3) utilizing it. This presents a multitude of complex problems, since the primary energy sources, coal, oil, natural gas, nuclear fuel and hydraulic power have vastly different environmental effects. Consequently, trade-off decisions which should be made between the different energy sources to minimize the environmental impact are not at all straightforward or easy. Based on the technical trends rough cost estimates may be made for pollution control in the future. However, it is not possible to quantify the hidden costs of pollution and estimate the price of continuing as we have in the past.

There are two general approaches to our environmental problems. The first proposes that technological improvements can be made and can reduce the environmental impact of energy use to tolerable levels. The second approach questions our per capita consumption levels and suggests population be controlled until an ecologically balanced society results. People may in the future have to forego some conveniences and pay higher prices for certain goods and services, including energy. Present-day public opinion appears to favour the first approach and the bulk of this report is concerned with the means by which this approach may be achievable, in-

asmuch as it may offer the most palatable strategy for the near future. However, a growing number of people support the second method, which is now a matter of debate involving a basic change in the structure of our society. This view will probably gain wider acceptance as more and perhaps irreversible changes of the environment are observed.

For the purposes of this study, a provisional energy consumption forecast has been prepared (Figure 1). It is based on an exponential growth for the next twenty years. Clearly, any society cannot continue to expand in this manner over a period of time. This report summarizes relevent information on the environmental impact of energy use in Ontario for the next twenty years as outlined in Table 1. Additional detailed information has been prepared and entered into the files for the Advisory Committee on Energy.

Section II of this paper contains some general background material followed by summaries of the environmental impact of obtaining, processing and utilizing energy in Sections III(a), III(b) and III(c) respectively. Some comments on new or anticipated environmental legislation in North America are given in Section IV. Section V covers the projected environmental quality by 1991. Although it is somewhat beyond the scope of this study, some attention has been given in Section VI to the future implication of unrestrained growth and potential climatic changes, which could occur in the next century.

FIGURE 1

FUTURE ENERGY CONSUMPTION IN ONTARIO

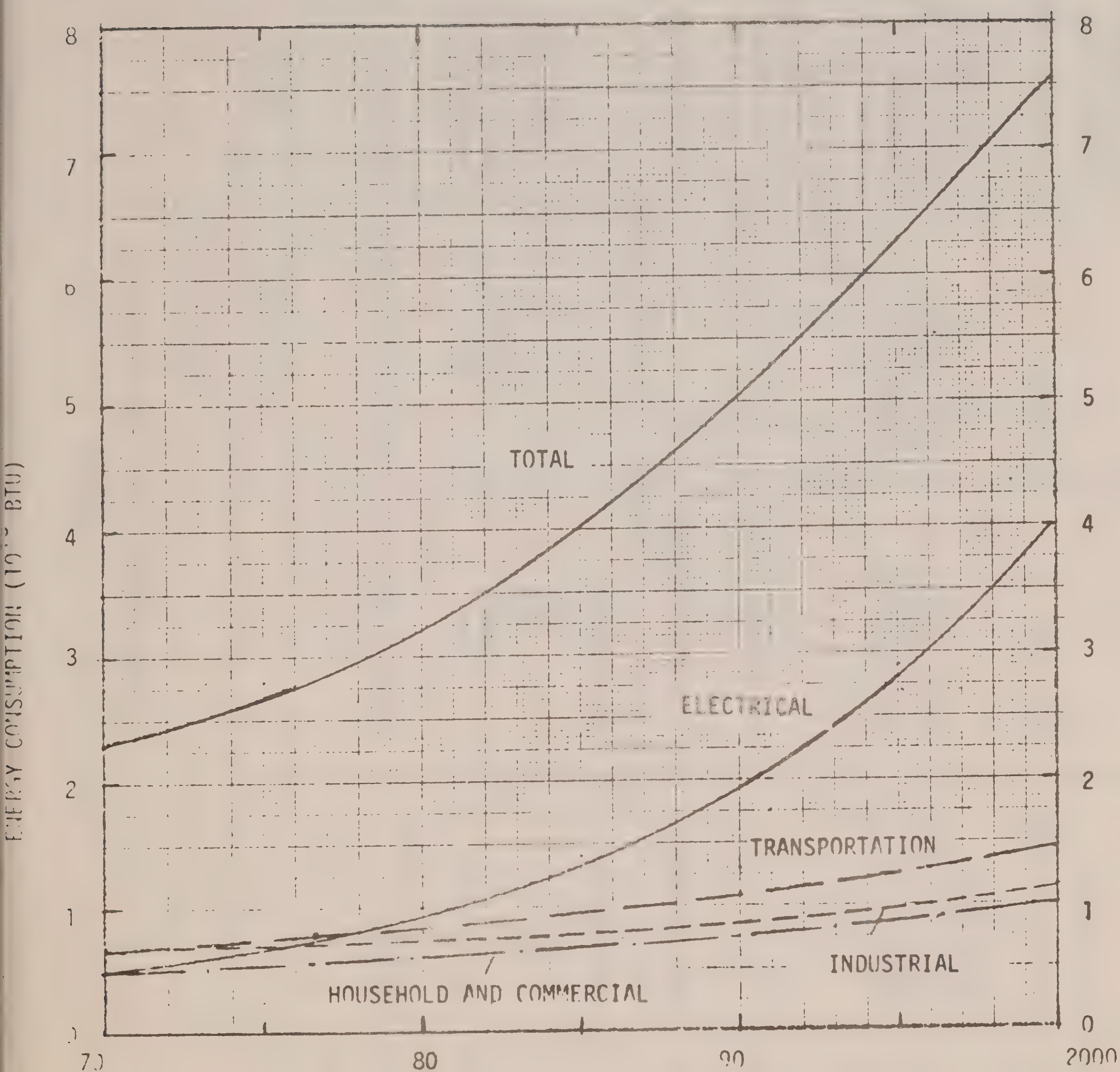


TABLE I

ENVIRONMENTAL IMPACT OF ENERGY USE

		Energy Sources				
		Coal	Oil	Natural Gas	Nuclear	Hydro
EFFECT ON AIR	Obtaining					
	Processing, etc.	Dusting Coke Emissions	Refinery Emissions	Handling Emissions	Radioactive Dusts	
	Utilizing	Particulate SO_2 NO_x Heavy Metals	CO NO_x CxHy SO_2 Heavy Metals	NO_x CxHy	Accidental Spills Regular Losses Cooling Tower Evaporation H_2S Emission	
EFFECT ON WATER	Obtaining	Acid Drainage	Potential Spills		Acid Drainage	Altering Water Shed, Natural Flow
	Processing, etc.		Accidental Spills		Dissolved Salts Radioactive Waste Disposal	
	Utilizing	Increased Local Temperatures Dissolved Salts Large Cooling Water Flow	Increased Local Temperatures Large Cooling Water Flow	Increased Local Temperatures Large Cooling Water Flow	Increased Local Temperatures Waste Disposal Large Cooling Water Flow	Fluctuating Stream Flows, Lower Flow Rates
EFFECT ON LAND	Obtaining	Disturbing Land	Pipeline	Pipeline	Disturbing Land	Disturbing Land
	Processing, etc.	Solid Waste			Radioactive Waste Disposal	
	Utilizing	Solid Waste Disposal	Waste Disposal		Waste Disposal	

Section II

ENVIRONMENTAL IMPLICATIONS OF ENERGY USE

SOME OF THE PROBLEMS

This section discusses the known and expected environmental degradation caused by energy use on the air, water and land. In most cases, degradation occurs in more than one facet of the environment. Corrective measures to improve one environmental problem frequently result in further degradation of another environmental quality. Therefore, it is necessary to consider all environmental impacts and closely co-ordinate control measures to obtain an acceptable total environment.

Effects on Air

The impact of processing and using energy, is the dominant factor affecting the quality of the air. Many emitted contaminants pollute the atmosphere, however five major pollutants comprise by far the major load, (1) particulate matter, (2) sulfur dioxide, (3) carbon monoxide, (4) oxides of nitrogen and (5) hydrocarbons[(1)*]. These contaminants are most prevalent in urban centers.

An example of the atmospheric degradation resulting from the utilization of energy in an urban area is shown by the inventory of air pollutants in the Toronto area[(2)]. Table II illustrates that about 90 percent of the air pollutants in Toronto are a direct result of energy utilization in transportation, electrical power generation and heating. The automobile is the greatest single source accounting for 56 percent of the total pollutants (mainly carbon monoxide). The two electrical power generation

*The superscripts in parenthesis correspond to similarly numbered references at the end of this report.

TABLE II

AIR QUALITY MODEL FOR METROPOLITAN TORONTO

EMISSION SUMMARY - BY POLLUTANT

February, 1972 Inventory

(Percentage figures shown in brackets refer to contribution of each source type to a specific pollutant)

	Millions of Pounds Emitted Per Year				
Source Type	SO_2	PARTICULATE	NO_X	CO	HC
R. L. Hearn G.S.	34.64(7.12)	0.61(1.12)	26.38(12.74)	0.28(0.03)	0.11(0.06)
Lakeview G.S.	348.28(71.59)	5.94(10.94)	80.19(38.73)	2.00(0.23)	0.81(0.43)
Municipal Incinerators	0.55(0.11)	12.13(22.34)	1.[illegible](0.65)	3.28(0.38)	0.16(0.09)
Industrial Sources	25.99(5.34)	12.03(22.16)	18.[illegible](9.17)	5.29(0.62)	45.93(24.33)
Autos	3.49(0.72)	4.65(8.56)	43.6[illegible](21.08)	827.36(97.04)	126.42(66.96)
Railroads	0.40(0.08)	1.08(1.99)	2.17(1.05)	0.60(0.07)	1.33(0.70)
Shipping	0.90(0.19)	0.40(0.74)	0.66(0.32)	0.24(0.03)	0.32(0.17)
Aircraft	0.24(0.05)	1.18(2.17)	1.44(0.55)	2.21(0.26)	10.61(5.62)
Heating - Residential	19.82(4.07)	2.49(4.59)	5.91(2.85)	0.52(0.06)	0.76(0.40)
Heating - Apartments	20.05(4.12)	7.84(14.44)	10.02(4.84)	8.07(0.95)	1.68(0.89)
Heating - Schools	5.51(1.13)	0.68(1.25)	1.81(0.87)	0.27(0.03)	0.09(0.05)
Heating - Commercial Buildings	19.03(3.91)	3.39(6.24)	12.05(5.82)	0.82(0.10)	0.38(0.20)
Small Industries	7.19(1.48)	0.83(1.53)	2.54(1.23)	0.23(0.03)	0.10(0.05)
Incineration: Apartments, Schools, Small Industrial and Commercial Buildings	0.43(0.09)	1.05(1.93)	0.20(0.10)	1.44(0.17)	0.09(0.05)
TOTAL - (in brackets, % of total pollutants)	486.52(27.19)	54.30(3.04)	207.06(11.57)	852.61(47.65)	188.79(10.55)

stations generated an additional 28 percent of the total pollutants (mainly sulfur dioxide). Detailed data of this type are not available for Ontario as a whole; however, the trends are expected to be somewhat similar to Toronto's for other urban areas. Improvements made in urban areas by the use of higher stacks result in increased ambient pollutant concentrations in the rural areas.

The production and existence of smog is another urban air pollution problem distinct from the one outlined above [3]. Under the influence of sunlight, the oxides of nitrogen and gaseous hydrocarbons interact to form a complex variety of secondary pollutants called photochemical oxidants. These compounds, together with the other liquid and solid particulates in the air, are commonly known as smog. Automobiles and to a lesser extent electrical power stations are the prime contributors to photochemical smog. Because sunshine and still atmospheric conditions are needed to provide the energy and time for these reactions, it is apparent why the problem has arisen in Los Angeles, but is, at least as present, not severe in Ontario.

Effects on Water

The obtaining of energy by mining can cause acid drainage or radioactivity problems in the adjacent watercourses. These substances deny portions of the downstream watercourse for other uses. The disposal of radioactive wastes from mining has caused significant water degradation[4]. The utilizing of energy has both a physical and chemical effect. Large volumes of cooling water discharge required for fossil-fired and nuclear generating stations change both the local temperature and natural movement

pattern at the discharge. Chemical by-products are also introduced into the water stream[5]. The physical effects of once-through cooling systems can be both beneficial and detrimental.

There has been a large amount of discussion about discharging the waste heat from electrical power generation stations into the water. The main concern has arisen in the United States where large power plants have been located on relatively small and warm lakes and rivers[6]. It is well-known that heat accelerates the biological decay process in water and reduces the capacity of the water to retain dissolved oxygen and other gases. Thus, heated water can assimilate less biological waste. On the other hand the growth of aquatic plants including algae is accelerated. Also, increased water temperatures can interfere with or disrupt the reproductive cycles of fish and migration patterns.

The short- and long-term effects on the fishery, biological activity and the chemical and physical characteristics of all aquatic areas are not completely known at this time. Studies to determine these effects in the area near the Nanticoke plant were initiated three years ago, but these studies will not be completed for several years. However, no significant physical, chemical or biological water degradation resulting from presently operating stations has been measured (although this may be due to a lack of baseline information collected before the plant start-up some years ago). Future stations may be larger by a factor of three and will in some areas cause major changes in the near-shore dynamics.

Normal sanitary and industrial wastes discharged into the water must conform to existing provincial requirements. Regulations regarding the re-

lease of radioactivity are presently under review by the Atomic Energy Control Board in co-operation with a number of Federal and Provincial agencies and revised water-quality objectives for radioactivity will likely be promulgated within one year. Specialized releases, like H_2S emanating from heavy-water plants, must also conform to existing provincial requirements.

Effects on Land

Mining of energy resources has historical implications of affecting the aesthetics and future land utilization. The increasing acidity of waters in mining areas are in part due to poor land-use practices[7]. While the major known energy resources within Ontario are restricted to lignite and uranium, the development of these resources must be regulated to ensure that the land environment is protected.

Hydroelectric power generation has direct effects on the use of land caused by varying the natural flow of streams and developing artificial impounding areas. Presently, most of the hydraulic potential for power generation in Ontario has already been developed and it is expected that future problems will be associated with flow regulations initiated to maximize power production.

Transportation of energy creates aesthetic problems associated with electrical transmission lines and occupies large land areas. The problem of an accidental spill from energy conveying systems on land or water transportation and pipelines is ever present and intensifies with population growth. The application of herbicides and defoliants to control vegetation growth on transmission line and pipeline rights-of-way may also give

rise to a variety of problems. Many of these compounds are very persistent and tend to be concentrated in living organisms. The ultimate effect of these substances is not well documented.

CAUSES OF PROBLEMS

Profit seekers are often blamed for the degradation of our environment. However, there are more fundamental causes. A large majority of people have been willing to consume vast amounts of resources and energy, failing to understand that the modern way-of-life is basically responsible for the deterioration of our water, air and land resources. The prosperity of a society is directly related to its ability to compete economically with others. Consequently, it is economically difficult for one group, one industry, one province or one country to justify accepting its environmental responsibility, if its neighbours or competitors do not. A multi-lateral approach is needed to effectively solve environmental problems. Its absence frequently only effects a partial solution. Unfortunately, this reasoning is more frequently becoming an excuse for no action.

Economic Incentives to Pollute

Our present pricing system fails to take into account the damage a polluter inflicts on others. Air, water and land are generally regarded as "free goods". As a result, this system produces very real, but hidden, "external social costs" which are imposed on consumers and non-consumer alike. Although there is considerable controversy as to the actual hidden costs of pollution, the Environmental Protection Agency (EPA) estimates

that the annual toll of air pollution in the U.S. on health, vegetation, materials and property values exceed $80 per person per year[8]. A somewhat lower, but similar, cost exists in Ontario. The cost of water pollution damage is less well documented. Clearly, there are increasing present-day losses in contaminated fish and potential future economic losses due to increased water-treatment costs. Costs of lost amenities and recreational opportunities are still more intangible, but none the less they are real economic costs. A price and/or tax structure that took environmental degradation into account could shift consumer preferences and perhaps discourage the purchase of goods which are manufactured by pollution producing facilities.

Population Growth

Population and consumption are the key to the environmental problem. Population growth was of no concern and encouraged in most parts of the world until a few decades ago. It has been somewhat difficult to recognize the potential problem in a country as sparsely populated as Canada, but when the weak life-support systems of much of our area are considered, there is greater cause for concern. Mushrooming population growth does not necessarily mean more polluted air and water, but it is more difficult to achieve and maintain environmental quality with the pressure of population growth in a given area. It is interesting to note that 20 percent of the world's population (North America, Europe and Japan) is considered responsible for about 90 percent of the earth's environmental damage[9]. An average North American is reported to be responsible for about the same impact to the environment as 200 people

in India or 50 in South America. The environmental impact of the population growth in Ontario will be increasingly felt.

Increased Urbanization

Our environment provides natural mechanisms to clean and restore itself. Some of these processes we understand, but most of them are still a mystery[10]. Concentrations of people in urban areas intensify the pollution problem. The increase in urbanization unfortunately continues to grow. For example, population forecasts for Ontario[11] indicate that the Toronto-centered region will grow faster than the remainder of the Province by the end of the century. Statistics have shown that in the U.S. increased pollution is directly related to increased population; similar data is not available for Ontario due to the limited number of cities.

The pollution domes of our cities as illustrated in Figure 2 are becoming visible. This dome, due to urbanization, changes the climate of a city as outlined in Table III[12]. Many may feel that higher temperatures and fewer heating degree days, particularly in the north, are an advantage, but few people enjoy less sunshine and increased cloudiness, fog and rainfall which also occur.

As urbanization spreads, we modestly alter our climate over a wider area and continue to magnify our pollution problems. Controlling or placing a ceiling on urban size and maintaining rural areas between urban centers may be necessary to minimize pollution effects.

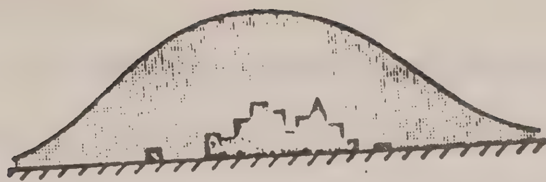
TABLE III

Average Changes in Climatic Elements Caused by Urbanization

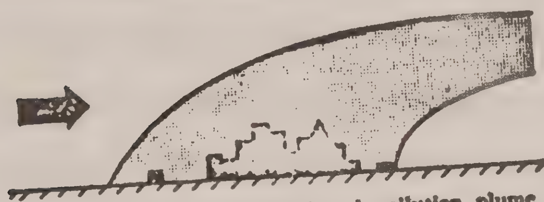
Element	Comparison with Rural Environment
Contaminants:	
condensation nuclei and particles	10 times more
gaseous admixtures	5 to 25 times more
Cloudiness:	
cover	5 to 10 percent more
fog—winter	100 percent more
fog—summer	30 percent more
Precipitation:	
totals	5 to 10 percent more
days with less than 5 mm	10 percent more
snowfall	5 percent more
Relative humidity:	
winter	2 percent less
summer	8 percent less
Radiation:	
global	15 to 20 percent less
ultraviolet—winter	30 percent less
ultraviolet—summer	5 percent less
sunshine duration	5 to 15 percent less
Temperature:	
annual mean	0.5° to 1.0° C more
winter minima (average)	1° to 2° C more
heating degree days	10 percent less
Wind speed:	
annual mean	20 to 30 percent less
extreme gusts	10 to 20 percent less
calms	5 to 20 percent more

(from Reference 12)

FIGURE 2



The urban dome.



The urban thermal and pollution plume occurring when a regional wind is blowing.

Other Factors

Our very way of life in North America contributes to a large degree to our mounting environmental problems. Our affluence places a strong emphasis on consumer goods. Advertising pushes us toward over-consumption and develops a throwaway psychology as the norm. Natural things are steadily displaced by synthetic things by our rapidly developing but uncontrolled technology. The consequences of some of these changes are already seen as negative.

Section III

ENERGY AND THE ENVIRONMENT

(a) IMPACT OF OBTAINING FUELS

Inasmuch as Ontario is an "industry rich and energy poor" Province and imports most of its energy resources, some of the environmental damage attendant to its energy consumption will not occur in Ontario. The Province is fortunate in this sense. However, it must be realized that the present price of some of Ontario's energy purchases does not reflect the true cost of the resource. While it is difficult to place a value on how others may be affected, it is apparent that the cost of such fuels will rise in the future as the government and people in these areas become more environmentally aware and costly pollution-abatement measures are undertaken.

An example of this trend may be found in the Appalachia coal-mining area in the U.S. The coal mining industry there spent 6.1% of its capital investment in 1969 on pollution control measures. This figure increased to about 8.5% in 1970[13]. With enactment of the pending Mined Area Protection Act[14] in the U.S., pollution-abatement costs and hence the cost of coal imported from that country, would be expected to continue to rise. This trend will exist also for fuels imported from other Canadian provinces. Fuels imported from the undeveloped areas of the world, however, particularly the Southern Hemisphere, would likely be subject to lower pollution-induced price increases over the longest period of time.

The following summary only applies to the impact on Ontario's environment of obtaining fuel.

Coal

At the present time all of the coal used in Ontario is imported and hence produces no pollution problems here. However, the Onakawana lignite deposits in Northern Ontario are being considered as an energy source[15]. While the available technical information concerning the Onakawana lignite deposit is sparse, fairly accurate generalizations can be made with regard to the probable environmental impact of mining the deposit.

Water Pollution

Since the Onakawana lignite deposit is overlain by an average of 65 feet of silt, sand and boulder clay, it appears unlikely that a conventional underground mining plan could be followed with any degree of safety. Consequently, a surface method of mining which would minimize the impact on the environment could be followed. A specific method is suggested in Reference 16.

The spoil heaps in the coal-producing Appalachia region of the U.S.A. generate acid mine drainage problems. However, the spoil heaps of the Onakawana deposit will not generate acid mine drainage, because;

(1) The material covering the Onakawana deposit consists of sand, gravel, limestone, shale and clay, which was deposited in the area as a result of glaciation. Iron sulfides which produce acids do not occur to any significant extent.

(2) The overburden is quite alkaline in nature and will, in all probability, neutralize any acid that might be generated.

The Onakawana River, however, runs directly across the extent of the deposit, as it is currently known. Consequently, if the water quality of the Onakawana River and other streams in that drainage basin are not to be affected by mining operations, considerable quantities of lignite adjacent to the rivers will have to remain untouched. Alternatively, the river itself might be diverted (into the Abitibi River) before it reaches the mining area. However, detailed ecological studies of the area should be made prior to selecting this approach.

Publications from Australia indicate that lignite mining faces are continually subjected to a water spray in order to avoid spontaneous combustion. If water sprays are required at the Onakawana property, turbid runoff could occur. Due to the nature of the operations, however, runoff problems of major proportions are unlikely to develop.

Finally, it is suggested that the deposit should not be developed unless the rehabilitation procedures required under the terms of Section 168 (1) of the Mining Act closely follow mining operations. The natural surface of the landscape would be entirely destroyed but spoil (waste) piles can be recontoured and revegetated as mining progresses. Also, the recontoured waste piles should be revegetated with species native to the area. In this regard, revegetation and proper contouring will be difficult if not impossible during the long winter months.

In summary, regardless of the size of the proposed mining operation, no uncontrollable or unusual water pollution problems should arise. Acid

mine drainage should not be a problem. Obviously, processes such as mining under wet conditions and coal washing could give rise to turbid effluents in the streams of the area. Land rehabilitation should and could be undertaken as mining proceeds.

Air Pollution

The mining of the Onakawana lignite should not cause any major air pollution problems.

Impact on Land

Past experience has shown in a variety of ways, that nature as a whole is in a state of dynamic equilibrium. It may be expected that mining and industrial activities in the James Bay area will affect this equilibrium[17]. Environmental problems, which could occur, may be intensified when the environment is imperfectly understood, and especially when it constitutes special problems of temperature and drainage as does the northern regions in Ontario. The capacity of northern ecosystems for the assimilation and conversion of pollutants is not well-known.

The prospect of opening the Onakawana deposits and the planned development by the Province of Quebec of hydroelectric power sources in the area east of James Bay, will focus attention on the area, with its considerable potential in pulpwood, minerals, and water resources. The increasing demands for energy and food constitute pressures which may induce the eventual industrialization, land development and urbanization of this vast area, with attendant threats to the environmental quality and its complex ecosystem.

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The Province of Quebec has undertaken, or is planning, more extensive ecological studies of the natural environment[18]. The Ontario Water Resources Commission together with the Federal Government have carried out a five-year water resources study[19] but no ecological studies. The Department of Natural Resources has initiated plans to carry out ecological studies in this area[20a]. Initial phases have begun and a preliminary report on one aspect (wildlife inventory) has been submitted[20b].

The impact on land and the ecosystems, if the Onakawana lignite field is developed, is concerned with:

(1) The loss of the wilderness values of the area as a result of the probable open pit mining activity.

(2) The making of a large man-made body of water which may or may not be detrimental.

Notwithstanding the fact that some environmental studies are currently underway or planned, knowledge of basic biological processes in these undeveloped northern regions is still scarce. Consequently, it is recommended that significant development of the region should be preceded by a comprehensive investigation, which could be undertaken jointly by Ontario, Quebec and the Federal Government.

Oil

Water Pollution

Oil production produces a very small impact on the aquatic environment in Ontario. At present, drilling is banned on all of the Great Lakes except Lake Erie, from which gas only is taken. In the event that oil production

is allowed on Lake Erie or the other Great Lakes, the consequences on the aquatic environment could be significant and would have to be evaluated in detail. The environmental concern centers about the possibility and consequences of accidental oil spills during drilling and production operations.

Air Pollution

To date the oil producing areas have not produced significant air pollution problems. No future problems are expected unless massive new deposits are located.

Impact on Land

The impact on land from oil drilling activities is concerned with:

(1) Staking and locating procedures in the field.

(2) Access road location and construction to the drilling and well sites and line cutting, etc., in connection with geological and magnetometer surveys.

(3) Location of drilling sites.

(4) Waste-disposal practices.

(5) Prevention of accidental spills and fires.

In the above, the main goals are to minimize the impact on forests, fish and wildlife nabitat, landscape and aesthetic values through the application of approved plans and methods before, during and after the various stages of action required in the exercise.

Should oil or gas deposits in Northern Ontario be located, broad-based ecological studies, as outlinedpreviously for the Onakawana area, should be carried out before development proceeds.

[illegible]

(9) [illegible]

In the above, the main [illegible] to minimize the impact on forests, fish and wildlife habitat, [illegible] and aesthetic values through the application of approved [illegible] methods before, during and after the various stages of activity [illegible] in the exercise.

Should oil [illegible] in Northern Ontario be involved, broad-based ecological [illegible] as outlined previously for the Onakawana area, should [illegible]

Gas

Gas wells in Ontario are primarily restricted to offshore drilling rigs in Lake Erie. These rigs have presented a hazard to fishing gear in the past but are now fitted with equipment to fend off nets. These wells have not had a significant impact on the aquatic environment. At present most of the sources are distant from population centers and thus present a minimum air-pollution problem.

Uranium

Hundred of deposits of uranium-thorium minerals are known to occur in Ontario. At the present, however, production comes only from Elliot Lake and Bancroft areas. By 1991 Canada may have 30,000 to 50,000 MW of installed nuclear power plant capacity of the CANDU type. As a result the total nuclear fuel requirements will be modest compared to known reserves. The world's total nuclear power plant capacity may be over 30 times that of Canada; consequently, the availability of world markets and the desire for exports may determine if a significant quantity of Ontario's uranium is to be mined, and what the subsequent impact to the environment may be.

The discussion below covers the environmental impact of mining and milling uranium because this first processing step occurs in the mining areas. The impact of further refining the uranium ore is discussed in the next section.

Water Pollution

The mining of uranium results in a significant impact upon the aquatic environment[21].

Vein and pegmatite deposits tend to be relatively small and do not contain significant (from an environmental standpoint) quantities of reactive (iron) sulfide minerals. The Bancroft deposits are of this type. Serious environmental problems such as the generation of acid mine drainage do not occur as a result of mining and milling these deposits[21].

Approximately 80 percent of the present Canadian production, however, comes from the pebble conglomerates of the Elliot Lake district. These conglomerates, unfortunately, contain significant concentrations of (iron) sulfide minerals which, at present, have no economic value. Discarded as waste, these sulfides react to form acid-producing water soluable salts, causing acid, mine-drainage problems[21].

The disposal of uranium mining wastes, using practices which were considered to be standard in the mining industry, has resulted in serious long-term radiological and chemical pollution of the waters of the Serpent River basin[4]. The main sources of the problem are the waste-water discharges from both active and abandoned tailings areas, which have resulted in (1) increased radioactive Ra-226 levels in almost all waters of the basin, (2) severe depression of pH and excessive increases in dissolved solids, sulfates and nitrogen levels, and (3) sharp reductions in fish population and other forms of aquatic life.

The most significant impairment was evidenced by increases in Ra-226 in the water by factors of 50 to 200 over the background levels in certain lakes, which decreased linearly with distance downstream from the emission location. Average Ra-226 levels in the basin are shown on Figure 3.

FIGURE 3


QUIRKE LAKE BASIN
OLD QUIRKE
SERPENT RIVER
BUD LAKE
NEW QUIRKE
PANEL
ROCHESTER CREEK
WILLIAMS L
DENISON
DUNLOP LAKE
SERPENT RIVER
QUIRKE LAKE
STOLLERY LAKE
108
CAN MET
LONG L
SPANISH AMERICAN
HALF MOON LAKE
KINDLE LAKE
STANROCK
MAY LAKE
CROTCH LAKE
ELLIOT LAKE BASIN
PECORS LAKE BASIN
McCABE LAKE
STANLEIGH
SHERIFF CR
SHERIFF L
WHISKEY LAKE
ELLIOT LAKE
MILLIKEN
LACNOR
HOUGH LAKE
HORNE L
WESTNER L
SERPENT RIVER
PECORS LAKE
ELLIOT LAKE
ALGOM NORDIC
QUIMBY LAKE
N NORDIC L
ESTEN L
NORDIC LAKE
DEPOT LAKE
McCARTHY LAKE
MARSHLAND LAKE
TROUT LAKE
GRANDEUR LAKE
Ra - 226 pCi/l
30 +
20 - 30
10 - 20
3 - 10
<3
LOWER SERPENT RIVER BASIN
SERPENT RIVER
TURTLE CR
108
CAMP L
LEGEND
SAMPLING STATIONS
SAMPLING AND FLOW MEASUREMENT STATION
SAMPLING STATION
MINES
TAILINGS AREA
PRONTO
SPRAGGE
SERPENT RIVER
17
SERPENT RIVER
GRASSY L
SERPENT
NORTH CHANNEL (LAKE HURON)

Levels above 3 pCi/l exceed the desired water quality value. Since changes in other water quality parameters generally followed a similar pattern, the Ra-226 distribution can be used as a general indicator of water pollution in the basin.

Significant quantities of radioisotopes have been concentrated by the aquatic organisms. Although some radioactivity was absorbed by fish, consumption of fish flesh appears to present no public health hazard. Finally, the residents in uranium mining areas do receive slightly higher doses of radioactivity than persons in the rest of the Province. The main source of the increased dose is the use of water.

The main impairments in the chemical quality of the waters were the serious depression of pH and the 8 to 15 fold increases over background levels of dissolved solids, hardness, sulfates and nitrogen. The flow-through time for the largest lake in the system is estimated to be about 3 to 4 years. Thus, it may take several years before the effects of neutralization of the seepage and wastes can be measured. However, once the pH levels in the watershed are restored, ammonia may become a serious hazard to aquatic life and will, therefore, have to be reduced.

Table IV summarizes the pollutant waste load for the Elliot Lake region, corresponding to a production of 4500 tons of uranium oxide. Without corrective measures these wastes will increase directly with increasing production.

TABLE IV

Waste Loading into Serpent River Basin (1966-1969)[4]

Type		Yearly Average
Ra-226	microcuries/day	4,300
Alpha Emitters	microcuries/day	39,000
Beta Emitters	microcuries/day	38,700
Dissolved Solids	lb/day	301,000
Total Nitrogen	lb/day	8,300
Sulphates	lb/day	171,000
Iron	lb/day	2,100
Chlorides	lb/day	8,500

In the future, the uranium mining industry must revise its practices for use of water and waste disposal systems. The following steps are necessary for the protection of environmental quality in the mining areas:

(1) Stabilization and maintenance of all abandoned tailings areas to secure, in perpetuity, their containment including isolation and cover, erosion control and, as required, treatment of seepage and runoff should be provided by the mining companies or their successors responsible for the disposal sites. Provincial legislation dealing with stabilization of tailings areas by vegetation or other methods should be extended to include abandoned areas and, as required, treatment of seepage and runoff.

(2) Mining companies should pursue the use of improved waste treatment techniques such as sulfide removal, and if necessary, ion

exchange, reverse osmosis, etc., should be considered to improve the chemical quality of mill wastes and tailings. First priority should be given to the control of pH and toxic compounds such as heavy metals and ammonia.

(3) Use of lake basins for containment of tailings at new mining locations should be prohibited.

(4) Further studies are needed to examine the total human intake of radioactivity through air, food and water in those areas where waters containing significant quantities of radionuclides are used for domestic water supply. It is expected that the radiation dose resulting from short-term use of these supplies may not present a significant hazard to health; however, it would be advisable to consider alternate supplies since any unnecessary exposure to radioactivity should be kept to a minimum.

(5) Further studies are needed to define the levels of dissolved solids, particularly sulfates, necessary for restoration and maintenance of a healthy balance of the aquatic life.

Air Pollution

In some areas of the world airborne radioactive substances have been identified as responsible for increased occasions of lung cancer[22]. In mining uranium the main problem is gaseous radon and its decay products. Forced ventilation through stacks is usually used with air-cleaning equipment and as a result, the quantity of airborne dust released to the atmosphere is usually very small. Dilution in the atmos-

phere makes their concentrations insignificant relative to the amount of these gases normally present.

While the residents of the uranium mining and milling areas are exposed to somewhat higher levels of radioactive wind-blown particles, this is a minor source and does not represent a serious health problem[23]. Future increased levels of uranium mining will increase the atmospheric levels of radioactive substance.

Impact on Land

The impact on land from uranium mining activities is concerned with:

(1) Prevention of increase of radioactivity in soil, plants and animals.

(2) Disposal of the mine wastes in or over the land.

(3) Staking procedures in the field and access-road location and construction for prospecting and mining.

In the above, the main goals are to minimize the impact on plants, wildlife habitat, landscape and aesthetic values through the application of approved plans and methods.

(b) IMPACT OF PROCESSING AND TRANSPORTING FUELS

Coal

Coal mined in North America, unfortunately, tends to have a rather high sulfur content, which produces serious sulfur dioxide emission problems. In the future, coal may be desulfurized prior to combustion. This processing is one of several possible abatement methods; however, it is more convenient to discuss this possibility in terms of utilizing energy.

Water Pollution

It is not expected that the transportation or processing of coal will create future water-quality problems.

Air Pollution

The unloading and storage of coal at power plants results in localized wind-blown dusting. This can be partially controlled by the use of additives. Further, the use of air curtains (that is sheets of moderate velocity air) shows good promise for the containment of such dusts[24]. New installations should be equipped for the prevention of wind-blown coal. It is believed that present technology can control these dusting problems in the future.

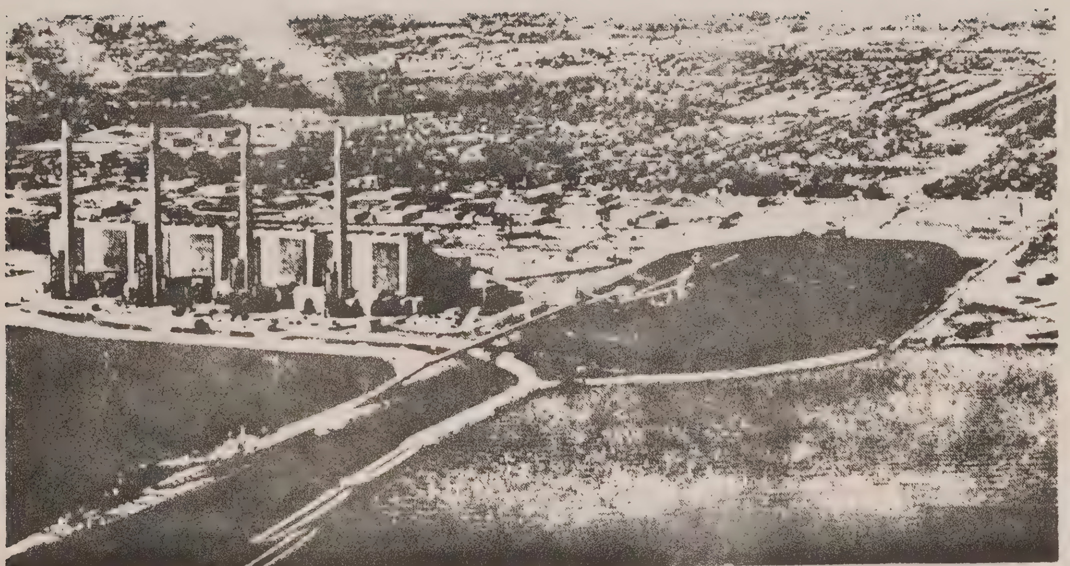
Large consumers of coal require extensive stockpiles (as shown in Figure 4), and these together with their continuous relocation produce local air-pollution problems which are of major importance to the neighbouring residents up to perhaps two miles. Future stockpiles will become both larger and more numerous, but this problem can be handled in the future by largely existent technology. Ontario Hydro is currently working toward better containment methods[25].

Oil

Water Pollution

A potential danger to the aquatic environment is the possibility of a major spill arising from either a pipeline break or a collision between vessels transporting oil. In the report of the International Joint Commission on the Pollution of Lake Erie, Lake Ontario and the International

FIGURE 4



View of Lakeview Generating Station, including coal pile, near end of shipping season.

Section of the St. Lawrence River, it is stated;[26a]

> "although the likelihood of a major oil spill on the lakes is fairly remote, the risk is real and continuing. The loss of 1000 tons of bunker fuel or similar petroleum product would be enough to pollute extensive areas of the lake and many miles of shoreline. The immediate consequences of such a disaster would be the damages to water supplies, bathing beaches and other recreational facilities, as well as the destruction of large number of waterfowl. The effects of oil pollution on the littoral ecology are largely unknown but experience elsewhere indicates that some of the methods used to remove or disperse the oil are more harmful than the oil itself."

In order to minimize the adverse effects which would almost certainly result from a major spill, a comprehensive programme for combatting spills must be developed. In this regard, an Interim Province of Ontario Contingency Plan for spills of oil and other hazardous substances[26b] has been formulated but has not yet been established as effective and viable solution to the spill problem.

Because a massive spill on the Great Lakes or connecting waterways might affect the U.S.A., both Federal[26c] and International[26d] Contingency Plans have been developed. Depending on the severity of a spill, the Province of Ontario Contingency Plan only might be implemented, however, if an escalated response was necessary, the Federal Plan would be implemented. If U.S. waters were being affected, then

the International Contingency Plan would be implemented. All three of these Contingency Plans have been formulated to complement each other in the event that an escalated response is necessary.

Because the potential for spills will increase significantly in the future as the consumption of petroleum products increases, it is recommended that contingency planning activities receive a high priority within the Ontario Government and that an effective spill response capability be developed as quickly as possible.

The petroleum refining industry generates a number of waste chemical products which are discharged into the water; phenols, oil, ammonia, dissolved hydrocarbons and chlorinated hydrocarbons are a few. These however have no bearing on electrical power generation and will not be discussed here.

Air Pollution

While oil refineries produce a number of significant air-pollution problems, none of these are associated with the use of energy resource for electrical power generation. However, they will be covered in the final report.

Impact on Land

Inasmuch as both crude oil and petroleum products travel by pipeline, a summary of the impact on land is partly covered in the section dealing with gas pipelines.

Several separate problems attend oil pipelines. Because the pipelines carry very large volumes of oil between gate valves, this presents a

serious but local problem from the released oil on the land, unless it is close to a population center in which case the danger of fire is considerable. Environmental damage in oil-soaked areas is considerable, usually resulting in denuding of vegetation, especially if crudes or light fuels are involved.

Experience in the U.S. indicates that ground water may be contaminated in instances of disposal of oil-soaked material or dirty oil by burying. Although evaporation would be of assistance in a surface spill, the shallow nature of much of Ontario's ground water could pose problems.

Gas

There are no water- or air-pollution problems associated with the transportation of natural gas with the exception of an accidental release of the fuel. The problems attendant to production of gas through coal gasification are described later.

The impact of transporting and processing gas by pipeline is concerned with:

(1) Location of the pipelines.

(2) Access road location and construction.

(3) Location of gas-line pumping stations and other facilities.

(4) Waste-disposal practices.

(5) Maintenance procedures and methods.

(6) Prevention of accidental spills and fires.

In the above, the main goals are to minimize the impact on forests, fish and wildlife habitat, landscape and aesthetic values through the applica-

tion of approved plans and methods before, during and after the various stages of action required is the exercise. A summary of past practices and desired procedures for pipeline construction and maintenance is given in Reference 27.

Uranium

The processing of nuclear fuel, beyond the milling operation, causes a number of potential pollution problems[28].

The refining of ore concentrates received from the mills and the production of uranium dioxide (UO_2) for use in the CANDU system result in solid wastes and spent chemical solutions requiring treatment and disposal. Further, the production of heavy water, used by moderators in the CANDU system, also represents a pollution potential, and the reprocessing of fuel elements could lead to serious waste-disposal problems.

Water Pollution

(a) <u>Uranium Dioxide (UO_2) Production</u> - The refining of ore concentrate received from the mills and the production of uranium dioxide (UO_2) for use in the CANDU system is carried out as part of Eldorado Nuclear's refinery operation in Port Hope. Due to the lack of market, the UO_2 plant has been closed for three years, and no current operating data is available. At present, uranium dioxide for existing contracts is manufactured from a stockpile of the intermediate product, ammonium diuranate. The ore concentrate contains 15 - 35% impurities which are removed, precipitated with lime, and disposed of as solids. In the past, the leaching of radium and arsenic from the dump sites has been a problem. The problem has arisen as a result of poor land-disposal-practices utilized prior to 1967.

A leaching problem is not expected to arise from the cut and fill process used since 1967. The feasibility of treating the wastes, prior to the lime treatment, to precipitate the arsenic and radium in forms which will be less susceptible to leaching is also under study.

Spent chemical solutions containing nitrate and ammonium ions represent a further disposal problem. Utilizing the waste loading figures of 620 lbs. nitrate ion and 220 lbs. ammonium ion per ton of UO_2 produced and the projected requirement of 10,000 tons of UO_2 per year for Ontario reactors in the year 2000, it can be estimated that 3100 tons per year of nitrate and 1125 tons per year of ammonium will be discharged as by-product. It is expected however that a satisfactory method of treatment will be developed before the expected waste loadings materialize.

In summary, it is believed that treatment methods will be developed that will prevent the wastes from the refining of uranium having any significant effects on the water quality by 1991.

(b) <u>Heavy Water (D_2O) Production</u> - Deuterium, a heavy isotope of hydrogen, is present in fresh water at a concentration of about 150 mg/l. The process for separation and concentration of this naturally occurring deuterium depends on an enrichment process based on the temperature-dependent equilibrium between hydrogen, deuterium, and hydrogen sulfide (H_2S).

The Bruce Heavy Water Plant, located at Douglas Point, Ontario, has been designed to produce 800 metric tons per year of heavy water from a feed of about 13,500 U.S. gpm of Lake Huron water. This plant, which will be the largest of its type in the world when completed, will have a total

inventory of 1,200 tons of hydrogen sulfide in the process equipment when in operation.

Under normal circumstances, the only H_2S released in the liquid waste from the heavy-water plant will be present in the 13,500 gpm process waste stream. This stream, with a design maximum H_2S concentration of 1 mg/l, will be discharged into one of two lagoons each of which has a three-hour retention time. Because the lagoons are aerated, it is expected that the concentration of H_2S will be reduced to an extremely low level, although precise estimates of the lagoons performance cannot be made due to a lack of data for H_2S treatment systems of this type.

There will be two other significant aqueous waste streams from the Bruce Heavy Water Plant and these are the discharges from the two separate cooling water systems. These discharges, of 75,000 U.S. gpm each, will normally contain no H_2S. It is to be expected, however, that minor leaks may occur and if so, these will result in some H_2S gaining access to the cooling-water flow.

Because of the possibility of some H_2S leakage into the cooling water, and because it is also possible for the lagoon effluent to contain some residual H_2S, the OWRC has approved the waste treatment facilities on the condition that the maximum loading of H_2S to Lake Huron over a one hour period will not exceed 18 pounds. This loading corresponds to an H_2S concentration in the combined effluent of 0.09 ppm, which is within the limits considered safe for fish.

It is possible, of course, that failure of certain process equipment

could result in "spills" of H_2S in concentrations far above those expected during normal operation. The probability of such failure is low, however, and therefore the plant is not expected to present a serious threat to the aquatic environment.

Air Pollution

Airborne effluents from nuclear fuel processing beyond the milling operation vary in terms of volume, concentration, and chemical composition, depending upon their origin. All these operations in fuel processing are potential sources of radioactive airborne dust.

(a) Fuel-Fabrication Plants - Dust or fumes are controlled by conventional gas cleaning equipment[(29)]. Dust emission consist essentially of uranium or thorium compounds involved in the process. The gases evolved from a fuel-processing plant are usually contaminated with such chemicals as nitric acid and organic solvents, as well as with fission products, depending upon the particular process employed. Since fuel processing requires treating effluent gases to remove minute quantities of radioactive materials, it removes many of the nonradioactive components as well. In these operations, the relatively high economic value of the product material makes it unlikely that significant air contamination will occur in normal operation conditions.

(b) Fuel-Reprocessing Plants* - In order to extend the supply of nuclear fuel, reprocessing is highly desirable. When a reactor core has reached the end of its useful life, only a small amount of ^{235}U will have been

*Fuel reprocessing is not necessary for the CANDU system. However, this section was included in the event that if other reactor systems are used in Ontario; or if, economic incentives may dictate fuel reprocessing in the future.

consumed by fission and an additional amount of ^{238}U will have been transformed to ^{239}Pu. The fuel, with its inventory of fission products, may then be removed from the reactor and transported to a chemical processing plant where uranium and plutonium are recovered for use in new fuel elements.

Even though the fuel is stored to provide time for radioactive decay, a large quantity of highly radioactive material is still present when the fuel reprocessing begins. The greatest potential danger of air contamination arises at a fuel reprocessing plant.

As yet, there are no fuel reprocessing plants in Ontario, however, it is a reasonable assumption that such a plant will be established during the time interval of this study. Consequently, some of the environmental problems, which could arise, are outlined here.

The most critical problem of air pollution from a potential fuel reprocessing plant is possibly the release to the atmosphere of ^{85}Kr (half-life of 10.8 years). Location of the fuel-reprocessing plant in the site of favorable weather conditions and the use of high stacks are possible methods to keep ^{85}Kr ground-level concentrations below a permissible ambient level of 10^{-7} mci/cc. Eventually, the discharge of noble gases may be prohibited during the reprocessing of nuclear fuel. A number of methods for ^{85}Kr removal from gas streams are available and include; room temperature absorption on charcoal, silica gel, or molecular sieves, low temperature absorption on charoal or molecular sieves, cryogenic distillation and scrubbing, extraction by liquids, and thermal diffusion. These processes are at various stages of development, and most can remove more than 90% of the ^{85}Kr.

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Gases can be stored for radioactive decay until meteorological conditions are adequate for dilution and dispersion in the atmosphere. This technique will probably be favoured by the nuclear industry, but should be officially discouraged.

The fact that radioactive substances can cause damage to people, plants and animals and can enter food chains is well known. Since its inception, the nuclear industry has been aware of the potentially hazardous affects of its wastes. Standards for permissible concentrations of radioactive pollutants in the environment have been established. However, the permissible release standards are to be questioned because they are 10 to 100 times higher than what is actually being released. This situation is discussed more fully in a subsequent section dealing with nuclear power plants. In any event, effective containment and disposal methods are absolutely necessary for fuel reprocessing plants.

(c) Heavy-Water Production - The operation of a heavy-water plant involves large quantities of hydrogen sulfide, which is used for the enrichment process.

During the normal operation of the plant there are continuous emissions of H_2S via a flare stack where provisions are made for combustion of the gas.

A summary of the sources of H_2S and possible ground level concentration emissions from a heavy-water plant is given in Table V[30]. In the event of an upset condition in the process, some of the equipment may have to be isolated and vented to the atmosphere via the flare system and con-

TABLE V

Sources, Operations and Concentrations of H_2S Released from a Heavy Water Plant

Source/Operation	H_2S Emitted to Flare	Ground-Level Concentrations of H_2S p.p.m.	
		With Ignition	Without Ignition
Normal operation	yes	.001	.001
Storage and loading	no	-	-
Process draining	yes	0.33	1.3
Emergency venting	yes	0.81	100
Major failure	no	500	500

sequently the ground-level concentrations of H_2S would exceed the Ontario Ambient Air Criteria of 0.25 ppm for one hour. The frequency of such upset conditions is unknown at this time, but it is expected to be higher at the start-up of the plant and decrease as more experience is obtained.

Emergency venting through the flare stack is a remote possibility, but in the event of such an occurrence, up to 900,000 lbs. of H_2S per hour would be released to the flare and the ground-level concentrations would exceed the criteria.

A major failure in a critical piece of equipment, (the rupture of a storage vessel) could cause the release of 400,000 lbs. of H_2S within an extremely short period of time. Dangerous concentrations, which may severely affect human life, can be expected as far as 14 miles from the source. The probability of a major catastrophe is considered to be very low. A contingency plant to cope with such an event is presently being developed and is almost complete.

(c) IMPACT OF ELECTRICAL POWER GENERATION

Figure 1 shows that over the next two decades electrical power generation will become the biggest single consumer of our energy resources, inasmuch as Ontario appears to have little further potential for hydro power except in the far north. Unfortunately, fossil-fuel or nuclear power plants produce a variety of emissions which pollute the air and they discharge large amounts of waste heat into the water or air.

Electrical utilities, including Ontario Hydro, have long recognized the need for planning far in advance for future facilities. However, until

a few years ago they have not had to take into account their overall effect on the environment. Although work on emission control techniques has been tremendously accelerated over the past four or five years, the presently available engineering technology is inadequate to meet our present needs. Power companies over North America are faced with increasing demands for electricity, but their plans for expansion and satisfying this demand are being blocked by citizen groups concerned with conservation and the environment. It appears probable that Ontario Hydro will face increasing pressure from the public in the future. Recent formation of an Interdepartment Task Force on Generation Station Siting is a good first step in gaining widespread acceptance of future planning.

Air Pollution

Fossil-Fuel Plants

The air pollutants emitted from fossil-fuel plants obviously depend upon the type of fuel used. The types and quantities of emissions from the burning of different fuels are shown in Table VI[31]. The lower levels of solid particulate and sulfur dioxide emissions result from the use of gas, which illustrates why many power plants in North America have been converted to this fuel. However, due to the fact that many organizations are solving their immediate emission problem in this way, the supply of natural gas will become very restricted in approximately a decade or so if it is used as a general solution. Consequently, it already appears advisable to limit the use of natural gas to other situations

where alternative emission abatement solutions would be prohibitively expensive.

Oil reserves appear sufficient for several decades, while the known reserves of coal indicate an adequate supply for several centuries Consequently, we have concentrated on the effects of using primarily coal and secondarily oil, in future fossil-fuel plants.

(a) Solid Particulate emissions for all practical purposes are under reasonable control in large power plants. It is now largely a matter of satisfactory operation and strict compliance with the regulations. A number of systems are available for dust or fly-ash control. However, electrostatic precipitators offer the best long-term solution, even though they are massive and costly as shown in Figure 5. Ontario Hydro appears committed to this direction as indicated by the following quote from a recent Hydro publication[32],

> "All the coal-fired stations are fitted with dust-collection systems to contain the fly-ash. The older stations have combined mechanical and electrostatic dust collections and the newer ones have electrostatic dust collectors only. The policy is to achieve a minimum of 99.5 per cent dust-collection efficiency on all new boilers, but efficiencies are lower than this for some of the older installations."

(b) Sulfur Dioxide control represents today's air-quality battleground for electrical power generation industry[33, 34]. Sulfur oxides (about 99% SO_2 and 1% SO_3) can be controlled through four basic approaches:

(i) Dispersion from tall stacks.

(ii) Substituting low-sulfur fuel.

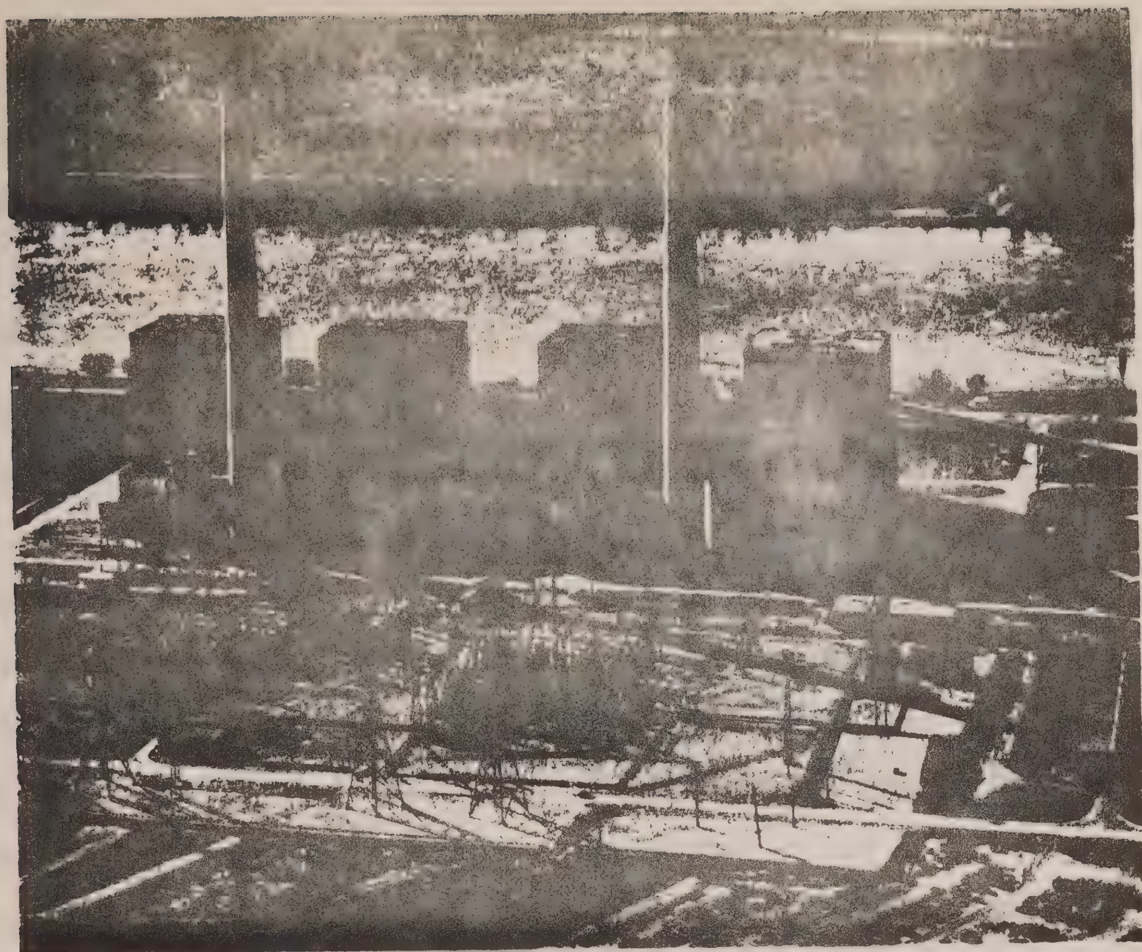
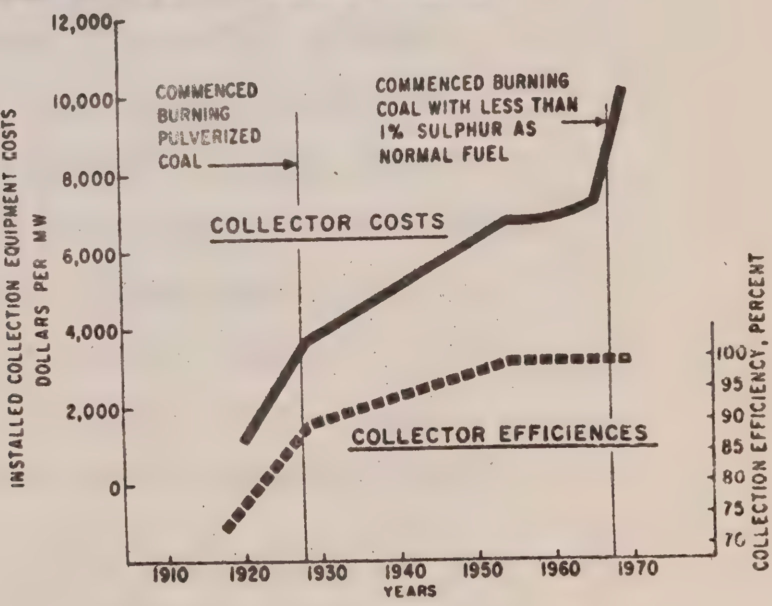


FIGURE 5A

FIGURE 5B



Increase in cost of dust-collecting equipment in the Con Edison system, after Ramsdell and Soutar.[3] The figures are corrected to present day costs, and include material and erection costs of collector, flues, support steel, and dry ash conveying facilities.

(iii) Removal of sulfur oxides from the flue gases.

(iv) Desulfurizing existing fuel.

Each of these approaches also has several alternatives, and there is an abundance of literature attempting to shed light on this complex situation.

(i) Dispersion from Tall Stacks

The use of tall stacks and increased dispersions has been hotly debated in several countries over the past two or three years[35]. Although the Ontario regulations under the Environmental Protection Act permits dispersion from tall stacks as a means of controlling atmospheric sulfur dioxide concentrations, the government has made it clear that this is an interim measure and is only permitted when there are no practical means of controlling the pollutant at the source.

(ii) Substituting Low-Sulfur Fuel

As outlined previously, natural gas contains little sulfur, and power plants fired with gas contribute essentially no SO_2 to the atmosphere. However, the supply of natural gas is limited, and with proven resources shrinking rapidly, the use of this premium fuel by public utilities should be restricted. Other low-sulfur fuels are in limited supply at least in areas where they are needed. Crude oils from Western Canada, North Africa, Nigeria and the Far East are naturally low in sulfur, and fuel oil produced from these crudes generally contain less than 1 percent of sulfur.

The reserves of solid fossil fuel with less than 1 percent of sulfur are ample. However, this huge energy pool of sub-bituminous coal or lignite is found far from our consuming centers. Much of the remaining low-sulfur

bituminous coal is reserved for metal production. About one-half of the total known U.S. reserves of bituminous coal average 2.2 percent sulfur[36]. These reserves, mostly located in the eastern or mid-western states, are the main source of energy for conversion to electricity.

Samples taken from the Onakawana lignite deposit indicate a sulfur content under 1%[15]; however, if this fuel is compared with existing coal supplies on an equal energy basis it contains an equivalent sulfur content of about 1.5%.

It must be concluded that direct substitution to low-sulfur fuel has little real potential over the time-span of this study. Its only practical application is in critical areas, for example, the recent conversion of the Hearn Station.

(iii) Removing SO_2 from Flue Gases

Over the past 4 years great interest has developed in treating stack gases to eliminate SO_2 and more than 30 processes have been suggested. Some of these are obviously unsuited to a power plant. However, problems abound. The materials-handling problem alone is of a size seldom faced by engineers. A typical, large boiler furnace can send more than 50,000 tons of gas up the stack a day; even with SO_2 making up only about 0.25 percent of it, this means that 125 tons of SO_2 must be removed daily.

In considering the many different flue gas desulfurization processes, a distinction is made between recovery processes, in which a saleable

by-product, such as sulfur or sulfuric acid, is produced, and a non-recovery process, in which a disposable waste product is produced. The market for saleable sulfur products, particularly in Canada, is unfavorable[37]. The large excess of sulfur on the world market has reduced the f.o.b. price of Canadian sulfur to between \$4 to \$10/ton. The domestic demand for sulfuric acid is easily met with acid produced from smelter operations. Under these conditions there is little economic incentive to develop recovery processes, especially in Ontario, for the near future.

The most advanced or promising processes under development are reviewed in References 37 and 38. Ontario Hydro is seeking a satisfactory process for SO_2 removal[38]. In addition, the Ontario Research Foundation under contract to the Department of the Environment has made an independent evaluation of many SO_2 removal methods. Table VII summarizes the ORF evaluation of flue gas desulfurization techniques applicable to large power generation stations[39].

Of all the processes in varying stages of development today, the limestone slurry process (Item 6, Table VII), is judged by Ontario Hydro and others[40] to have the best chance of early development. This is a throwaway process in which the sulfur oxides in the flue gas are neutralized with limestone and converted to inert solids which can be disposed of in a sanitary land-fill. Several variations of this process are under development in North America, but operational problems continue to occur. Ontario Hydro is studying this system on a 400-cfm pilot-plant scale and is investigating the feasibility of a larger unit.

TABLE VII

Approximate Costs of Flue Gas Desulphurization

Process	Installed Capital Cost $/kW	Total Operating Costs Including Capital Charges ¢/MM BTU
1. Pittsburg and Midway Solvent Refined Coal	?	16
2. Messman Chemical Coal Cleaning	?	6-7
3. IGT Coal Gasification	~135	25.5
4. Garrett K_2CO_3 Process	13.5	7
5. Dry Limestone Injection	9	6
6. West Lime/Limestone Scrubbing	13	6
7. Stone and Webster Ionics	15	10
8. Chemico MgO Scrubbing	19	13
9. Monsanto Cat OX	32	16
10. Shell SFGD	26	16
11. Grillo AGS Process	?	12.5
12. Potassium Formate Process	15	7-8
13. Bischoff Process	?	15-19
14. Seawater Scrubbing	?	4

It is difficult to estimate the cost of any process that is not completely developed. Estimates made by Ontario Hydro differ significantly from those in Table VII made by ORF. Others[41,42] have estimated the operating costs of the limestone slurry process at between $1 and $4 per ton of coal. A figure of $2 per ton presents the consensus opinion. Further, capital investment cost estimates ranges from about $10 to $40 per installed KW with about $20/KW being typical. This control method could tentatively be planned for plants coming into operation late in this decade.

The limestone slurry process produces a waste by-product of calcium sulphate and calcium sulfite. It is expected that 0.2 tons of waste by-product will be produced per ton of coal burned and treated. In the SO_2 removal process, 60% will be in the form of solids which can be settled out and the remaining liquor can possibly be recirculated and reused within the system.

The settled solids may be left at the bottom of the lagoon or could be dredged out for removal to other disposal sites. These solid wastes are relatively insoluble and can be used in controlled landfill sites without too great a leachate problem. There is however, a possibility of a potential H_2S odour and appropriate measures would have to be taken to control this nuisance. If this sytem is adopted, then the planning aspect of coal-burning plants would have to take into account the land use requirement for disposal of this waste material from the desulfurizing of flue gases.

There is a secondary type of recovery and treatment process available where SO_2, sulfuric acid, sulfur and fertilizer compounds can be recovered as by-products; however, the use of this process would depend to a large extent on the available markets for these various by-products. It is not expected that these methods will be employed before 1985.

Faintly visible on the horizon is a new method of burning fuels which will greatly reduce emissions, the fluidized-bed combustor[43,44]. It involves a stream of air moving slowly through a bed of inert material. Such a system can become a combustor if the bed material is heated to about $1500^{\circ}F$ and a fuel, either oil or crushed coal, is admitted. If the bed material is limestone, the resulting lime will react with SO_2 as it evolves during combustion. Further, because the temperatures in fluidized system are uniform and can be held as low as $1500^{\circ}F$, little NO_x forms. The fluid bed would also be useful in removing any trace heavy-metal elements which exist in coal. A recent special study in fluid-bed combustors has been carried out in Ontario by Bergougnou[43].

The fluidized boiler would be the ideal tool for burning Northern Ontario lignites to produce power for gasification units at the mine-mouth. Such combustion would take place at relatively low temprature, $1500\text{-}2000^{\circ}F$, to avoid the formation of nitrogen oxides. Similarly, a fluidized-bed boiler could burn city garbage. It would also be used to burn high-sulfur oil residues in case these are needed as a temporary supplement to fuel gas. Existing pulverized-coal furnaces could be adapted to a low-pressure fluidized-bed combustion. A possible scheme could be to build a satellite

fluidized-bed boiler close to the existing power plant. Limestone would be injected into the bed to retain the sulfur in the ash. The rest of the air would be mixed with the gas coming out of the fluidized-bed boiler for firing in the existing boiler. Another possibility would be to build a LURGI gasifier and to use the low-BTU gas produced to fire the existing furnace.

Bergougnou suggests that power plants using fluidized beds burning solid fuel could be constructed about 1980 if a research and development programme, beginning in 1972, is emphasized.

(iv) Desulfurizing Fuels

On the average, half of the sulfur in coal is present as pyrites (iron sulfides) and half is combined chemically with the complex coal structure. Depending on the size of the pyrite particles, they can be removed. None of the organic sulfur can be removed without destroying the coal's molecular structure, e.g., by converting it into a fuel gas. Hence, about half the sulfur can be taken from coal by cleaning and at costs, for example, ranging upward to $1 per ton, adding some 15 to 30 percent to the fuel costs[45].

At the present time, the emphasis has turned on coal gasification as the best long-range approach to clean fossil fuel in large amounts. Coal gasification consists of the chemical transformation of solid coal into pipeline quality gas. This gas, primarily composed of methane, is virtually sulfur free and has a heating value of about 1000 BTU/ft^3. The United States has undertaken a major development programme in coal gasification[46] by the support of the methods listed in Table VIII.

TABLE VIII

US Coal Gasification Processes

Process	Laboratory	Sponsor	Federal Funding FY 1972
HYGAS (Electrothermal)	IGT	OCR-AGA	$3,500,000
HYGAS (Oxygen)	IGT	AGA	
CSG (CO_2 Acceptor)	Consolidation Coal Co.	OCR	3,420,000
SYNTHANE	BuMines	BuMines	1,500,000
BI-GAS	BCR	OCR-NCA	3,300,000
STEAM-IRON	IGT	Industrial	
FIXED BED	BuMines	BuMines	750,000
FIXED BED	Lurgi	Lurgi	

Assuming that a large lignite field exists in Northern Ontario, mine-mouth gasification would seem a promising solution to obtain fuel with low environmental impact. The rationale of coal gasification could be predicted on the basis of the following facts or assumptions: (1) It is cheaper to transport gas long distances than electricity. (2) Gas pipelines are less unsightly as they are commonly buried underground. Furthermore, they use less valuable urban and rural real-estate (100 acres per mile for high voltage transmission lines). (3) In electrical power generation, the availability of ash-free and sulfur-free fuel gas allows steam and gas turbines to be operated at higher temperatures. Altogether the increased efficiency resulting from a number of new power generation schemes operating on gas,

could more than pay for the cost of coal gasification[43].

Bergougnou[43] has also carried out an investigation of the environmental impact of coal gasification in connection with the possible development of the Onakawana lignite deposits. Although there are several potential air- and water-quality problems, the main environmental impact would come from the water evaporated from the lignite, which comes to the plant with slightly more than 50% water content. This water evolved by gasification is approximately equivalent to a daily rainfall of 1.3 inches over an area of two square miles. Severe local icing and fogging might result in winter. However, mechanical de-watering could considerably alleviate this problem. The sulfur produced would amount to 2260 tons per day, which would represent a serious stockpiling problem in the absence of markets. The leakage of SO_2 and H_2S to the atmosphere would be minimal. Dust entrained in flue gas leaving the lignite dryer would amount to about 15 pounds/minute if the dryers were equipped with two stages of cyclones and an electrostatic precipitator.

Additional details of the pollution aspects of lignite gasification as well as the environmental problems of burning it in a mine-site power plant are given in Reference 43.

The combined use of lignite gasification and fluidized-bed boilers appears very attractive for Ontario energy needs in the near future. Environmental deterioration would be minimal compared to present power schemes. An ecological study should be initiated for the lignite fields of Northern Ontario to determine, in detail, the impact of gasification on the local environment.

Fuel oil is more amenable than coal to desulfurizing: generally, the oil is treated with hydrogen to form hydrogen sulfide gas, which then can be separated from the liquid. This hydrodesulfurizing has developed strongly over the past few years, but the cost is still high. Desulfurizing fuel oil to acceptable levels costs from 50 cents to $1 per barrel[47].

The Ontario Research Foundation was asked to summarize the fixed and operating costs of various sulfur abatement alternatives. This comparison is shown in Table IX together with an estimate of the sulfur removal and time when the technique may be employed[39]. These cost estimates are perhaps accurate to 50%.

Coal, with a sulfur content now used by Ontario Hydro, is included to provide a base cost, and the cost of nuclear power is also included and observed to be nearly equal to current cost of power produced from fossil fuels. The non-recovery lime slurry scrubbing system would appear to increase the overall cost of a kilowatt-hour by about 8% and achieve a satisfactory reduction in sulfur emission.

It is difficult to compare the cost of SO_2 abatement with the indirect cost of no abatement, because there is no way to firmly establish the cost of the latter. The U.S. Environmental Protection Agency estimates that emitted SO_2 indirectly costs the public 10¢ per pound. This figure is debatable, but the President has proposed a SO_2 emission tax (see Section VI). One tax proposed, calls for an increasing rate from 5¢ per pound in 1972 to 20¢ per lb. after 1974 of SO_2 emitted[48]. As shown

TABLE IX [illegible] AND [illegible] SULFUR ABATEMENT ALTERNATIVES *

	I Coal a) Base 2.5% S	I Coal b) Low S <1% S	II Oil	III Natural Gas	IV Nuclear	V Mechanical Coal Cleaning	VI Chemical Coal Cleaning	VII Coal Gasification a) Bitumin.	VII Coal Gasification b) Lignite	VIII Oil Desulphurization	IX Flue Gas Desulphurization a) Recovery Schemes	IX Flue Gas Desulphurization b) Non Recovery Schemes	X Fluidized Bed Combustion
1. Capital Cost of Generator $/kW	136	136	111	111	270	136	111	111	111	111	136	136	NO RELIABLE DATA AVAILABLE
2. Annual Fixed Charges %	10.0	10.0	10.0	10.0	10.55	10.0	10.0	10.0	10.0	10.0	10.0	10.0	
3. Fixed Costs $/kW	13.6	13.6	11.1	11.1	28.9	13.6	11.1	11.1	11.1	11.1	13.6	13.6	
4. Cost of Fuel Inventory $/kW	0.5	0.62	0.80	-	-	0.59	0.70	-	-	0.94	0.50	0.50	
5. Fixed Operating Costs $/kW	1.14	1.14	0.91	0.83	1.33	1.14	0.91	0.83	0.83	0.91	1.14	1.14	
6. TOTAL FIXED COSTS $/kW	15.24	15.36	12.81	11.93	30.23	15.33	12.71	11.93	11.93	12.95	15.24	15.24	
7. Fuel Costs ¢/MMBTU	39	49	63	20	8	39	55	22	12	63	39	39	
8. Fuel Treatment ¢/MMBTU						8		37	30	11	7-20	6	
9. Piping Costs ¢/MMBTU				27				5.5	22				
10. TOTAL COST OF FUEL AT THE GENERATOR ¢/MMBTU	39	49	63	47	8	47	55	64.5	64	74	46-59	45	
11. Fuel Costs mills/kWhr	3.40	4.25	5.45	4.08	0.7	4.08	4.75	5.59	5.54	6.40	4.0-5.13	3.90	
12. Variable Operating Costs mills/kWhr	0.13	0.13	0.10	0.09	0.08	0.13	0.10	0.09	0.09	0.10	0.13	0.13	
13. TOTAL VARIABLE COSTS mills/kWhr	3.53	4.38	5.55	4.17	0.78	4.21	4.85	5.68	5.63	6.50	4.13-5.26	4.03	
14. Fixed Costs at 60% Load Factor mills/kWhr	2.90	2.92	2.43	2.26	5.70	2.91	2.42	2.26	2.26	2.46	2.90	2.90	
15. TOTAL COST OF POWER mills/kWhr	6.43	7.30	7.98	6.43	6.48	7.12	7.27	7.94	7.89	8.96	7.03-8.16	6.93	
16. Available by (approx.)	now	now	now	now	now	now	pilot	pilot	after 1983	now	Chemico* SFGD * Catox *	dry* dry/wet*1980	after 1980
17. % Reduction of SO_2 Emission	0	>60	0 to >60	100	100	40-60	70	95	95	70	Chemico >90 SFGD [illegible]	dry 50 dry/wet 30	90

in Table X such a tax which reflects the present indirect cost to the public is several times the cost of abatement.

TABLE X

Cost Benefit of SO_2 Abatement Based on a 1,000 MW Power Plant*

	Cost/year $ million
Use of Limestone Scrubbing (90% reduction of SO_2)	2.2 - 6.3
Use of 1% Sulfur Coal (60% reduction of SO_2)	2.14
Cost of Proposed Taxes on SO_2 Emission (at $0.10/lb. S) (90% taxed)	7.20
Estimated Damage of SO_2 - Emission ($0.10/lb. S according to US, EPA)	8.00

* For coal containing 2.5% S

(c) Oxides of Nitrogen (mainly NO and NO_2 and collectively called NO_x) are not being ignored by the electrical power industry in North America, although the major focus is still on abatement of SO_2.

NO_x forms in all high-temprature flames when nitrogen in the air reacts with active oxygen species in the flame. Generally, the higher the temperature, the more NO_x is produced.

In general, about 97% of the NO_x from stationary sources in Toronto comes from combustion process with the following approximate distribution[49];

	1971	1991 Est.
Electrical power generation	37.5%	51%
Industrial combustion	29.2%	26%
Residential & commercial combustion	10.4%	10%
Pipelines, refineries	19.9%	12%
Non-combustion	3.0%	1%

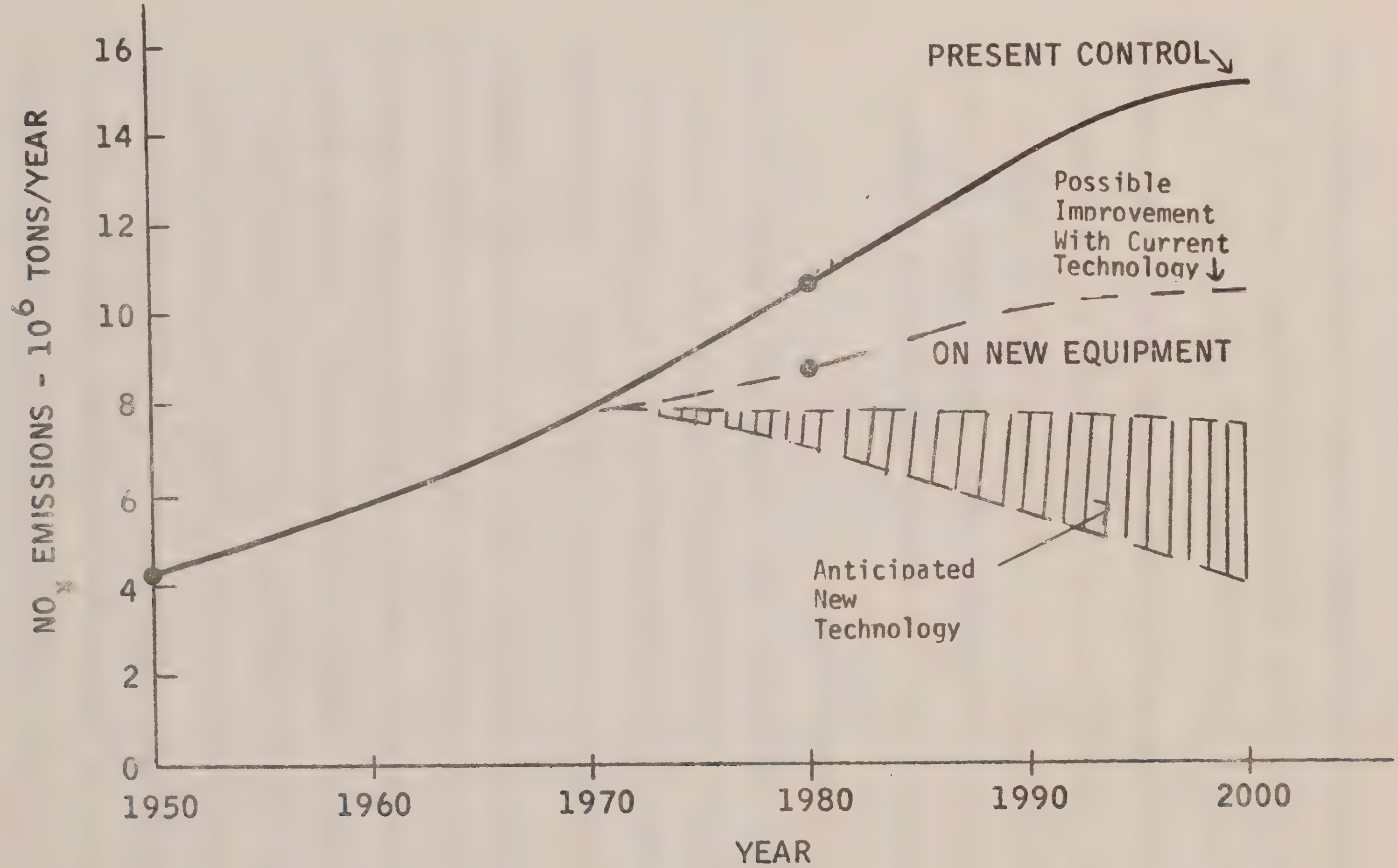
The trends in total NO_x emissions in the future are shown in Figure 6. Power generation plants are expected to produce a larger portion of the future NO_x due to their more rapid growth. Estimates of the future NO_x concentrations in the atmosphere contained in Section V indicate that it seems quite certain that power plants will be pressed to reduce these emissions in certain areas by the end of this decade.

Two basic procedures reduce NO_x emissions: burning at a temperature that is as low as possible, or operating the boiler furnaces to eliminate highly active forms of oxygen from the flame.

The Esso Research Corp. in the U.S. has completed an extensive three-year study evaluating future control techniques for NO_x[50,51]. As is the case with SO_2, many control methods have been suggested, (a) fuel modification, (b) altering combustion techniques and (c) flue-gas treatment. Of these the second is currently receiving the most attention and Ontario Hydro has, on a pilot basis, reduced the present level of emissions by about a factor of 1/2 to 1/3[52]. However, the NO_x control technology is not nearly as far developed as is that for SO_2 and moreover, the problem may prove in the long run to be more complex. The

Figure 6

POTENTIAL CONTROLLED NO_x EMISSIONS - STATIONARY SOURCES IN THE U.S.



future of NO_X abatement in the U.S. as viewed by the Esso study is depicted in Figure 6.

The curve labeled "possible improvement with current technology" indicates the best estimates of NO_X control to new equipment installed from 1970 to the years 1980 and 2000. Control methods in limited use at present, which have been effective for reducing NO_X emissions, include lower excess-air combustion, staged combustion, flue-gas recirculation, and changing burner location, spacing and configuration. The curve labeled "anticipated new technology" is based on wide use of potential combustion-control methods, such as steam or water injection and fluidized-bed combustion, combustion with oxygen in place of air, and flue-gas scrubbing.

The cost of NO_X abatement is still highly speculative. It is concluded, in Reference 50, that in some cases operating costs will be lowered due to improved combustion. Present estimates indicate a cost of about $1 to $3 million a year for stations such as Hearn and Lakeview, and be comparable to the SO_2 abatement costs.

(d) Heavy-Metal emissions into the atmosphere are possible because of the variety of impurities contained in fossil fuels as shown in Table XI. There is an increasing interest in "trace" or "exotic" pollutants in the atmosphere. These compounds may be extremely toxic, and low concentrations may damage flora or fauna, or become concentrated in the biosphere.

The measurement of these pollutants may be easier than evaluation of their effects. Most of the compounds and elements are present naturally in the environment, and the body can evidently dispose of certain levels of them.

TABLE XI

HEAVY METALS IN FOSSIL FUELS

Coal Used by Ontario Hydro

Element	Quantity, ppm
Nickel	7 - 10
Manganese	0.1 - 0.3
Zinc	0 - 5
Chromium	0 - 10
Cobalt	0.5 - 1.0
Lead	0.5 - 1.0
Molybdenum	11 - 16
Vanadium	0 - 10
Beryllium	0 - 0.05
Arsenic	0 - 10
Antimony	5 - 10
Cadium	0.1 - 0.3
Silver	0 - 5
Selenium	1.0
Mercury	0.6

Research is now required to evaluate the effect, of continuous exposure of the population to low concentrations of trace metals, in order to determine which are present in undesirable concentrations.

Ontario Hydro has been concerned about the emissions of a number of materials from its plants[52]. The programme undertaken includes a search for polynuclear hydrocarbons, especially benzo(a)pyrene -- and for fluoride, beryllium, selenium, nickel carbonyl, cadmium, antimony, bismuth and mercury -- in the coal, fly-ash and flue gas. Some of these substances may be carcinogenic. Because it is of great current interest, a detailed study of mercury emissions has been completed. It was found that 90 percent of the mercury in coal leaves with the flue gas with concentrations between 40 and 90 micrograms per cubic metre.

At the present time, heavy-metal emissions from these plants are not regarded as a significant hazard and are within the Provincial regulations. The emissions from power plants cannot be distinguished from other sources. However, heavy-metal emissions are being closely monitored in Ontario.

(e) Other Emissions

Radioactive substances may also be emitted by fly-ash coming from fossil-fuel plants. A recent collection of data describing these emissions is given in Table XII[53]. These emissions are discussed later in connection with nuclear power plants.

Other emissions in the form of carbon monoxide and hydrocarbons also occur. All power generation companies strive to complete the combustion of unwanted CO and unburned hydrocarbons, in flue gases, by completing

TABLF XII

Analyses of Radioactivity in Coal and Oil Fly Ash

Sample	Reference	Concentration (pCi/g dry fly ash) Ra-226	Ra-228	Th-228	Th-232
Appalachian coal ash	(4)	3.8	2.4	2.6	—
Utah coal ash	(4)	1.3	0.8	1.0	—
Wyoming coal ash	(4)	—	1.3	1.6	—
Japan coal ash	(4)	—	1.5	1.6	—
Alabama coal ash	(4)	2.3	2.2	2.3	—
Venezuela petroleum ash	(4)	0.21	0.49	0.67	—
TVA coal plants	(3)	4.25	2.85	2.85	2.85
Coal ash (Australia)	(2)	7.98	—	—	—
Oil fly ash[a] Turkey Point	(5)	0.18	0.17	0.82	0.17
Coal fly ash[b] Hartsville	(5)	2.3	3.1	—	3.1
Coal fly ash[c] Colbert, TVA	(5)	3.1	6.9	1.6	6.9
Coal fly ash[d] Widows Creek, TVA	(5)	1.6	2.7	2.8	2.7

the reaction and forming CO_2 and water. However, all of the combustion processses we employ are, slowly but steadily, increasing the CO_2 content of our atmosphere. In the long-range, this could produce serious climatic alterations well into the next century as outlined in Section VI. If these fears materialize we will have to turn to other methods rather than combustion to produce electrical power.

(f) Future Prospects

Public utilities are in business to generate electricity, not to process chemicals. Nothing could be wanted less around a power plant than a complicated chemical process for cleaning flue gas that might go awry and force an outage. The utilities would much rather burn low-sulfur fuel to eliminate SO_2 and modify the burners to prevent formation of NO_X However, some forms of chemical processing seems inevitable for coal- or oil-fired plants. From the information presented previously, it is clear that the abatement of air pollutant emissions from fossil-fuel plants will increase the cost of electrical power. Using consensus estimates it is believed that air pollution abatement programmes only for fossil-fuel plants may increase costs in the following manner as more control is used and certain types of fuel become scarcer.

Year	Price Index	Reason
1972	1.0	-
1976	1.10	SO_2 Flue Gas Abatement
1981	1.15	Some NO_X Abatement
1986	1.20	SO_2, NO_X and Trace Metal Abatement
1991	1.20	-

It should be emphasized that these crude estimates are only possible with our limited knowledge.

Nuclear Fuel Plants

In normal day-to-day operations, nuclear power plants are permitted by law to release radioactive substances to the environment in gaseous, solid and liquid forms.

The standards applicable to the operation of a nuclear station for effluent releases from the station are radiation dose standards set by the Atomic Energy Control Board, based on the recommendations of the International Commission in Radiological Protection.

As a matter of interest some common risks normally encountered at present are compared to those presently associated with the generation of nuclear power below[54]:

(1) Death by Auto Accident	1 in 5,000
(2) Occupational Death	1 in 10,000
(3) Death by Commercial Airplane Crash	1 in 100,000
(4) Death or Handicap by X-ray Diagnostic Dose	1 in 200,000
(5) Death or Handicap by Nuclear Plant Radiation	1 in 200,000

A certain amount of radioactive material is released routinely in the operation of a CANDU-type (Canadian Deuterium Uranium) power station both via the ventilation system and via the condenser cooling water. An extensive effort is made to minimize the release of primary coolant and moderator since it is heavy water and valuable. Other radioactive

releases are controlled, but an extensive effort is not made to reduce these to the absolute minimum. The primary released quantities are summarized below. Generally, they are only a fraction of the Derived (allowable) Release Limit (D R L).

Gaseous Effluents	Permissible daily releases (averaged over one year) Ci/day	Actual daily releases (averaged over one year) * Ci/day
Tritium (oxide)	4×10^{-2}	5.7×10^{-4}
Iodine - 131	7×10^{3}	30
Noble gases	5×10^{3}	4.4×10^{2}

Tritium is an activation product produced in the reactor by neutron bombardment of heavy-water moderator. It has a half-life of 12.5 years and represents a possible long-term hazard due to build up in the biosphere. Studies indicate that, even in an expanded power industry, in the year 2000 the annual increase in background dose due to tritium will be less than .001% of natural background dose[55].

Iodine-131 is a fission product and only appears if a defect occurs in a fuel bundle. Fuel defects have been occurring in CANDU reactors and small quantities of Iodine-131 have been released on occasions, but again, only a small fraction of DRL. Future improved fuel performance and ventilation system design are expected to reduce this even further. Exposure pathways for iodine are by inhalation and through foods (primarily milk).

* Values supplied by Ontario Hydro for the (200 MW) Douglas Point Prototype Station, which is a comparatively small station by present-day standards.

The radioactive noble gases may be fission products or activation products. The fission products are isotopes of Argon, Krypton and Xenon. Noble gases have so far been the major radionuclide group released and in some years have averaged 10% of the DRL. Improvement in fuel design and delay storage systems will help control emissions from future large multi-unit stations.

The amounts of radioactivity found in the environment as a result of present-day reactor operations are indistinguishable from those due to natural background and fallout from nuclear-weapon testing. Radiation caused by nuclear power stations can be kept well within the limits imposed by current radiation protection standards, but the question has been raised if this will be possible as more nuclear plants come into existence, or if allowable limits are reduced.

One of the fission product gases which is of concern if fuel reprocessing is undertaken in Ontario is Krypton-85 (10.5 years half-life). Sometime after the year 2000, Kr-85 released in fuel reprocessing could deliver a skin dose which is an appreciable fraction of the currently allowable maximum an individual is permitted to receive[56] and far more than will likely be allowed under future requirements.

The principal types of nuclear power plants presently in operation in the U.S.[56] are of a different type than the CANDU, and are also being considered by Ontario Hydro as possibilities in their planning. They utilize light water in the pressurized-water reactor (PWR) or a boiling-water reactor (BWR). Radiation exposure at the site boundary of the American systems are presently restricted to 0.005 rem/year, however, actual exposures are estimated to be considerably less than this. The

Americans are beginning to design plants with reduced emission levels. It is impossible to make a simple comparison of the effects of effluents from nuclear and fossil-fuel plants. Gas emissions from nuclear plants produce 'whole-body' exposure whereas radionuclides in fly-ash represent hazards to specific parts of the body. If the fly-ash is insoluble it lingers in the lungs; if it is soluble it passes into the blood and settles in the bone tissue. Some investigators have attempted to compare these emissions as fractions of total dose limits allowed by the International Commission on Radiological Protection (ICRP Dose Limit)[57]. The CANDU and American nuclear systems are compared to a coal-fired plant in Table XIII. This rough comparison illustrates that, from an air quality viewpoint, nuclear plants and coal-burning plants represent about the same hazard of airborne radioactive substances. Such emissions from coal plants can be decreased by better particulate control. The long-range concern is about the total amount of atmospheric radiation which will occur as more nuclear plants are built. This problem is discussed more fully in the next section.

Water Pollution

Fossil-Fuel Plants

The release of conventional (i.e. non-radioactive) wastes from thermal generating stations does not currently present serious environmental problems nor are such problems expected to arise within the next twenty years provided that the requirements of the Regulatory Agency are followed. Effluents, such as spent boiler clean-out solutions, water-treatment wastes and coal-pile drainage, are easily treatable at rela-

Table XIII

Comparing Radioactive Gas Discharges from Fossil and Nuclear Central Stations

Parameter	Coal plant	Pressurized-water reactor	Boiling-water reactor	CANDU* heavy water
Size, MW	1000	462	200	340
Stack discharge				
Fly-ash, gm/yr	1.5×10^9	-	-	-
Radioactive radium and thorium isotopes, mCi/yr	14.1**	-	-	-
Noble gases, Ci/yr	-	3.7	240,000	161,000
Liquid discharge				
Fission products, Ci/yr	-	3.8	6.0	-
Tritium, Ci/yr	-	1735	2.9	30
Dose limit (ICRP), micro-rem/hr	110	57	57	30
Dose limit per MW micro-rem/hr	0.11	0.12	0.29	0.09

* Douglas Point

** 99.5% Fly-ash removal

tively low cost, utilizing existing technology.

Discharges originating from wet ash-disposal systems however, may result in the release of unacceptable quantities of ash or dissolved solids to the aquatic environment, unless the disposal systems are designed to minimize such releases. Fly-ash is generally disposed of by dry transport, which poses no water pollution problems. At the Nanticoke plant however, a wet fly-ash handling system is being installed. Since a greater percentage of soluble material is present in fly-ash than in bottom ash (i.e. boiler slag), the transport water will contain unacceptable quantities of dissolved solids. Consequently, it is planned that the slurry water will be recirculated through a lagoon and re-used rather than discharged directly to the lake.

Unfortunately, there is a greater input of water to the lagoon than is re-used. As a result, a discharge to the watercourse of about 440 gpm is expected. The extent to which dissolved solids will build up in the lagoon waters is unknown. It is expected however, that the water will be saturated with the various salts leached from the fly-ash and the discharge of dissolved solids to the lake could conceivably exceed 25 tons per day per 1000 MW.

If future fossil-fuel electrical generation stations were to utilize a system similar to that at Nanticoke, and further, if the discharge of solids is the same as that possible at Nanticoke, significant quantities of dissolved solids will be discharged to the Great Lakes from each plant. It must be concluded therefore, that the only suitable method of fly-ash disposal for future plants is by means of dry transport or

by a completely closed recirculation system. The technology is available to implement this suggestion.

Nuclear Fuel Plants

(a) Radioactive Releases

The release of radioactive wastes to the aquatic environment is regulated and limited by the Atomic Energy Control Board. At the present time, the release limits are based upon the radiation dose limits for individual members of the public. They have been converted to concentrations of the various radionuclides in water, which will not provide an unacceptable radiation dose for a hypothetical group of individuals who might be drinking the effluent from the station and consuming fish that have grown in the effluent channel.

Experience with several reactors in Canada has shown that the actual release of radioactive wastes is only a fraction of the allowable releases, based on concentration criteria. This is due largely to the fact that concentrations are measured in the outfall, and reactor operation requires large quantities of water for cooling purposes. Using these vast quantities of cooling water as a sink for the disposal of active wastes has enabled the industry to largely avoid treatment of such wastes for removal of the radioactive constituents.

A typical CANDU nuclear generating station operating with a once-through cooling water system requires about 800,000 gpm of water per 1000 MW of generation capacity. Based on the approximate average flow rate of the St. Lawrence of 9.3×10^7 gpm, about 117,000 MW of nuclear capacity will utilize the equivalent quantity of water flowing through

the Great Lakes system.

If all of these future nuclear plants were to release the quantities of radioactive waste allowed by existing AECB requirements, the water and fish within the Great Lakes might eventually contain radioactivity to the extent that the maximum permissible radiation dose levels would probably be received by a significant segment of the population of the Great Lakes areas. Recently, the Atomic Energy Commission in the U.S. reduced the allowable releases of radioactivity from certain types of reactors by a factor of about 100, thereby bringing actual and allowable releases more in line with each other. The AECB is also currently considering the establishment of maximum permissible release criteria which will more closely approximate the actual releases from Canadian reactors. What is not known at this time is whether the new AECB requirements will, when implemented, require reactor owners to treat the active liquid wastes prior to discharge.

A comparison of allowable and actual releases of radioactivity from nuclear power plants shows that such releases can be held far below the quantities allowed under current standards. Such releases, however, could be still further reduced, sharply in some cases, by the application of proven economical waste-control measures.

"The issue involved is whether the nuclear industry should possess the right to pollute the environment or to expose members of the public to hazardous materials to a needless extent. If the nuclear power industry does, in fact, have such a right, then all other industries will insist on a similar right with respect to other contaminants. The solu-

tion is to require all industries, including nuclear power plants, to reduce and minimize all releases of contaminants to the full extent that is both technologically feasible and economically reasonable"[58].

To quote the International Commission on Radiation Protection (ICRP), "The maximum permissible doses recommended ... are maximum values; the commission recommends that all doses be kept as low as practicable, and that any unnecessary exposure be avoided". The U.S. Federal Radiation Council has stated the case as follows" "There can be no single permissible or acceptable level of exposure without regard to the reason for permitting the exposure. It is basic that exposure to radiation should result from a real determination of its necessity". From such admonitions, a policy of actively minimizing all human radiation exposure is clearly required of any responsible regulatory agency.

The question of how much radioactivity should be released to the aquatic environment for operations connected with the production of power is highly contentious. The necessity of balancing risk and benefit is obvious, but subject to great uncertainty. In view of the growing consumption of energy and the existence of other environmental forces directing us toward the installation of greater nuclear power capacity, and to ensure that the build up of radioactivity in the environment should not become an undesirable burden on future generations, it is recommended that the following policies be adopted;

(1) Radioactivity in the aquatic and atmospheric environments attributable to controlled releases from all operations should be kept to the lowest practicable level.

(2) The total burden of radioactivity in the water, sediments, and biota of the Great Lakes should not be allowed to increase by the discharges of radioactivity from nuclear operations.

(b) Thermal Discharge

Electrical power generation plants, whether nuclear or fossil fueled, have an energy conversion efficiency of between 30 and 40 percent. The fossil plants discharge a small part of their waste heat into the air, while all the waste heat from nuclear plants goes into the water.

The use of water for cooling purposes is a common practice in many industrial operations, and particularly important in the generation of electricity. Although thermal waste is common to both nuclear and fossil-fuel plants, nuclear plants produce substantially more waste heat per unit of electricity generated. Energy-conversion efficiencies for existing plants and some possible future improvements are listed below;

Type of Plant	Portion of Energy Converted to Electrical Power
Fossil fueled plant	38 to 40%
Proposed fossil plants with MHD topping cycle	53 to 59%
Present heavy and light water nuclear reactor plants	30 to 32%
Proposed advanced nuclear reactor plants	39 to 43%

The electrical-power industry has a strong economic motivation to improve these conversion efficiencies and reduce the amount of waste heat

they discharge. The prospects of a significant improvement beyond the limits shown above by the end of the century is rather dim.

The present controversy on thermal 'pollution' has arisen because of the phenomenal growth of the electrical-power industry, particularly in the United States, where many power stations have been built on relatively small lakes and rivers, and have sometimes caused significant ecological changes in the aquatic environment.

Predicting the effects of waste heat on the aquatic environment is only in the initial development stage. Since temperature is considered to be the primary control of life on earth, it is therefore important in a body of water. Because the surrounding temperature can determine the species that will live and reproduce, ecologists are deeping concerned with the threat to fish and other aquatic life forms which can occur in the future, because of increases in power demands.

One or more of the following effects may be induced by thermal discharges[59]. As water temperature rises in a river or lake, dissolved oxygen levels may decrease - a biologically important factor. Decomposition of organic (sewage) waste is accelerated by elevated temperatures, thereby further reducing dissolved oxygen levels necessary for the maintenance of a healthy habitat. There is a decrease in spawning success and in the survival of young fish. Normal biological rhythms and migration patterns are confused. Prey-predatory relationships are disrupted. Oxygen concentrations are decreased at the very time when more oxygen is needed by the aquatic life because of the increase in temperature.

Not only is the temperature of the water increased, but there are apt to be sudden changes in temperature, for example, due to shut-downs of the plant. It is therefore difficult for a new web of species, adapted to the warmed temperature, to become established[60].

Apart from other factors such as light and nutrients, heat may also stimulate algae growth. This is important from the aspects of water supply and recreation. Massive growths of algae increase water treatment costs. Also, if certain types of algae predominate, taste and odour problems can be experienced with the water supply.

There can also be beneficial effects of heat inputs to watercourses. In winter, heated water may prevent ice formation and promote navigation in water passages normally blocked, although the economic advantages of this seems questionable at present. Growing seasons can be extended and rates of growth increased for fish in their natural environment and in fish farms because of higher water temperatures. Swimming areas could be provided in certain cold-water lakes, thus increasing the recreational potential of those lakes. However, summertime algae growth may discourage swimmers and boaters. Utilizing the kinetic energy of the cooling water to induce local water-circulation may prove to be beneficial in improving local water quality. The Hearn plant cooling-water system is considered to enhance the water quality in the Toronto inner harbour by inducing a continuous circulation within the harbour.

Although thermal discharges are not known to be a serious problem in Ontario at this time, available information is inadequate and extensive studies are being undertaken on this matter, particularly with respect

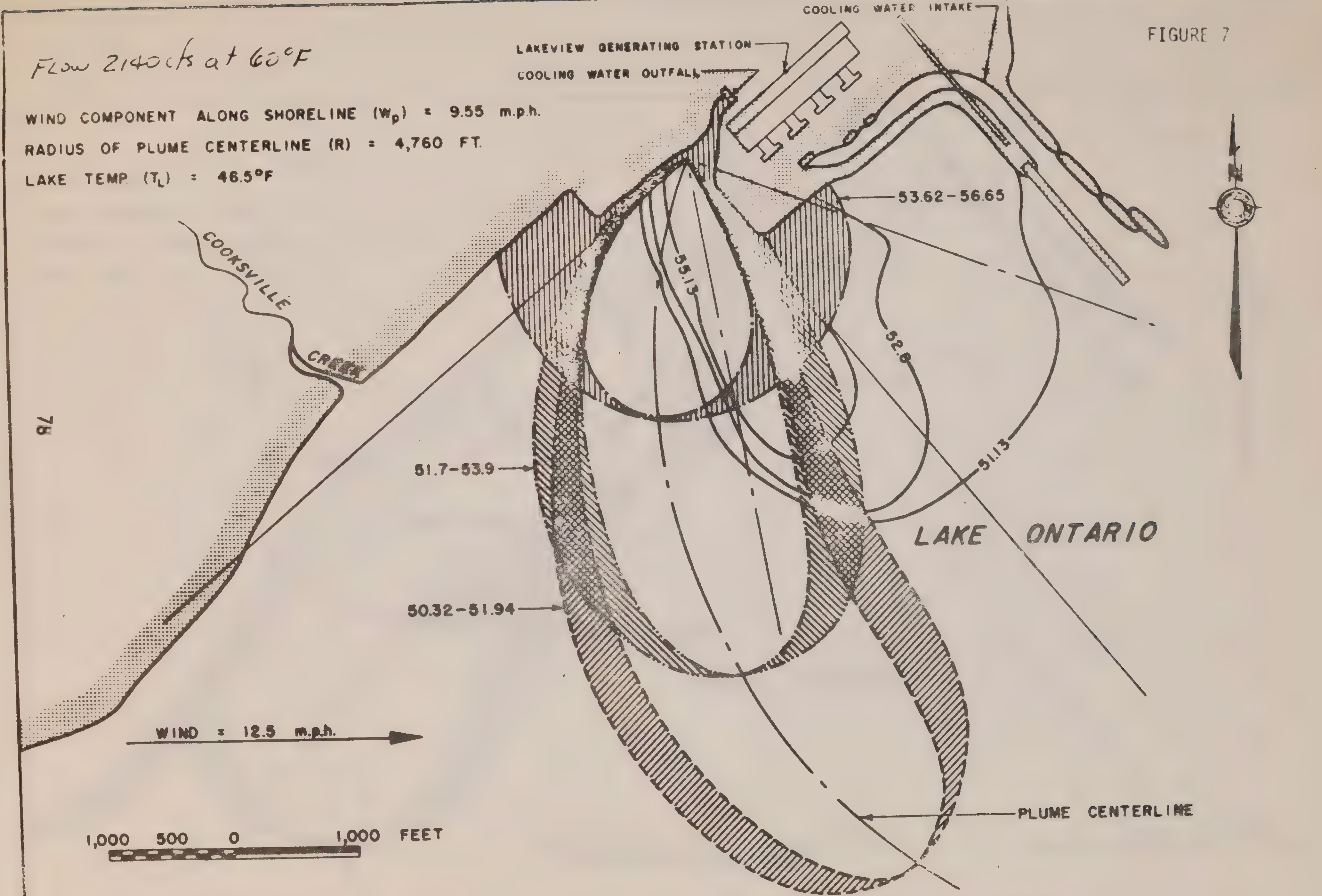
to the long-term effects. Further, the thermal characteristics and wat quality of the Great Lakes differs significantly not only from lake to lake but at different locations on a given lake.

Recent studies sponsored by the Federal Government[61] have indicated that waste-heat inputs to the Great Lakes are expected to increase substantially in the period between 1970 and 2000 (see Section V). As an indication of the magnitude of the thermal input, the total man-made input to Lake Ontario for one year in the year 2000 A.D. is 6 percent of the existing annual natural heat content variation within the lake.

Increases in average surface temperature (considering the whole lake) by the year 2000 are unlikely to have any dramatic effect on the ecology of Lake Ontario.

Local temperature increases in the area of the discharge may be significant. The thermal plume from the Lakeview generation station, for example, is detectable at distances greater than one mile from the discharge point on occasions (see Figures 7 and 8). Near shore dynamics are such that one would expect the thermal plume to be detectable in excess of one mile radius from the discharge point for a cooling-water discharge of approximately 2000 cfs at 16^{o}F above lake water temperature. (Proposed plants will discharge in excess of 10,000 cfs at similar temperatures.) It is now possible to estimate the physical extent of thermal plumes on lakes [62, 63, 64, 65, 66] and rivers[67]. However the long-term chemical, biological and modification of the local fishery effects are not known but are under study.

FIGURE 7



OBSERVED AND PREDICTED ISOTHERMS (NOV 13, 1969)

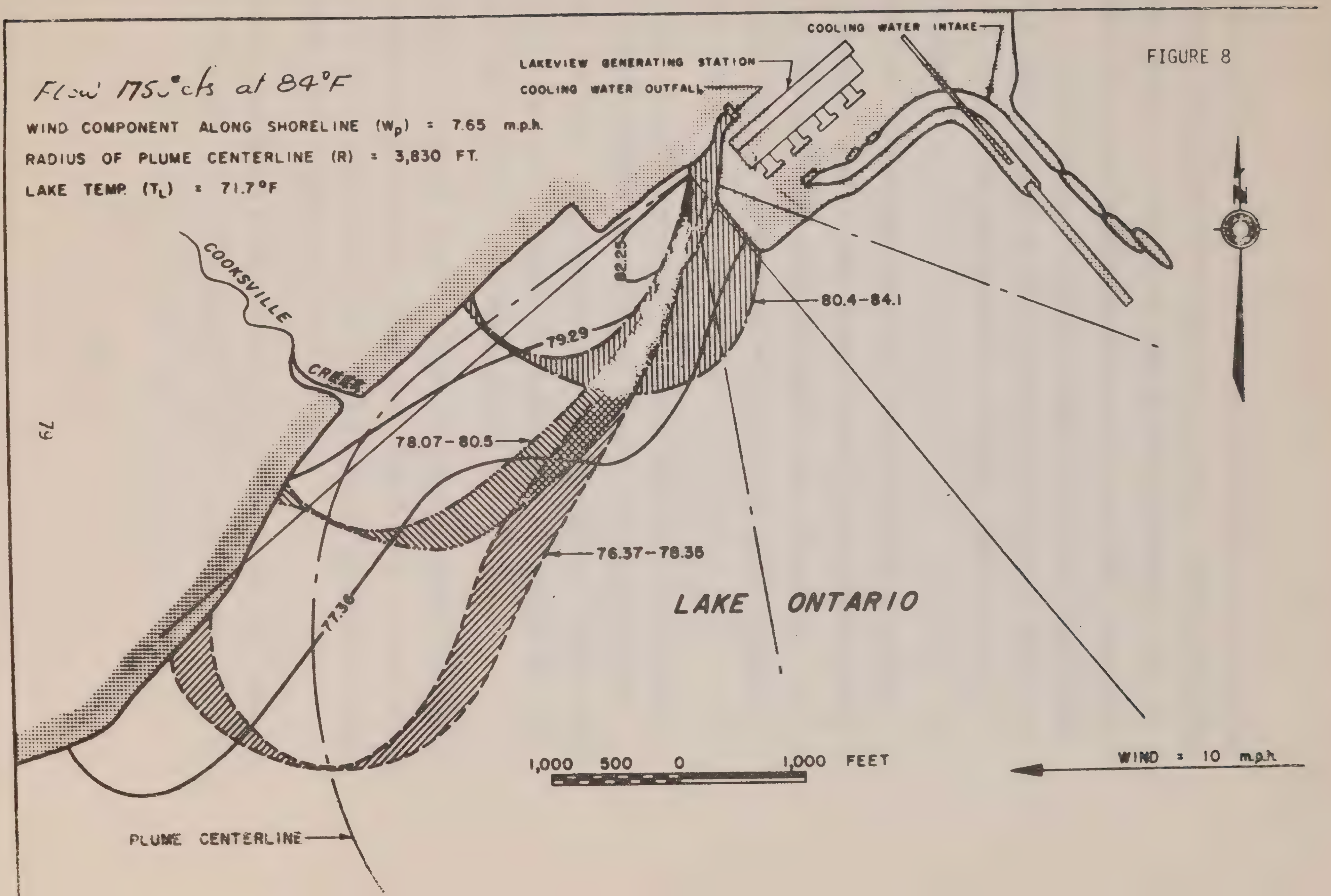

Flow 1750 cfs at 84°F
WIND COMPONENT ALONG SHORELINE (W_p) = 7.65 m.p.h.
RADIUS OF PLUME CENTERLINE (R) = 3,830 FT.
LAKE TEMP. (T_L) = 71.7°F
COOLING WATER INTAKE
LAKEVIEW GENERATING STATION
COOLING WATER OUTFALL
COOKSVILLE CREEK
82.25
79.29
80.4–84.1
78.07–80.5
76.37–78.35
77.36
LAKE ONTARIO
1,000 500 0 1,000 FEET
WIND = 10 m.p.h.
PLUME CENTERLINE

FIGURE 8

Lake Erie is a special problem. It has been despoiled by a wide variety of man's waste, predominately from the U.S. shore. Reference 61 states, that Erie will be receiving the same man-made heat input per unit surface areas as Lake Ontario between now and the year 2000. Because it is considerably shallower, its overall temperature increase and localized water temperatures may be much greater than those for Lake Ontario and it is expected that local fishery and biological activity will be affected.

Some areas are much more sensitive to thermal discharges than others. In particular, regions where nuisance levels of algae presently exist should be avoided (eg. western and central basins of Lake Erie, etc.). Thermal discharges should be avoided in known fish spawning grounds or in viable fishing regions.

Because the near-shore regions of the Great Lakes are highly variable in physical, chemical, and biological character and because many locations are unique, those organizations using the water for cooling should clearly demonstrate by appropriate studies that the discharge does not cause adverse effects at the discharge site.

In view of the unique features of Lake Erie and the possible overall rise in temperature over the next thirty years, Ontario Hydro has been advised by the OWRC to consider the installation of cooling devices on any future thermal-electric-generating station on Lake Erie.

The joint Canada-U.S. agreement, which is currently in the final stages of preparation, will likely contain objectives for discharges of heat to

the Great Lakes system. Finally, certain guidelines for governing thermal pollution of the Great Lakes and other waters of Ontario by electrical generating stations should be established:

(1) In those instances where harmful effects can be predicted, alternate cooling facilities, which will not seriously impact the environment, should be employed.

(2) In those instances where potential harmful effects may exist, but cannot be clearly predicted, power plants should be initially designed so that alternate cooling facilities can be added at such time as evidence indicates significant adverse effects.

(3) Cooling-water discharges should not alter local existing circulation patterns such that other water users are seriously depreciated, or spawning and fishing grounds are effected.

(c) Alternate Cooling Methods

The waste heat must be removed from steam electric-generating plants, but where should it be put? The most rational control method for thermal waste is to use the heat rather than releasing it to the environment. Yet very little work has been done, which might lead to practical present-day uses for this waste heat. Moreover, the inertia of our present "throw-away" policy is difficult to overcome. A study of potential uses of waste heat in Ontario has recently been completed[68].

It must be recognized that there are not many uses for waste heat rejected at the low-rejection temperatures, currently in use (50^{0} to $85^{0}F$). To make the best use of the waste heat the power plants will have to operate less efficiently and reject its waste heat at temperatures of 200,

300 and possible 400°F. Thus, the effective utilization of waste heat would have to be preceded by a completely different operating philosophy. Some possible long-range alternatives are listed below.

(1) Warm-water spraying or heating soil to extend growing seasons.

(2) Heating and cooling of greenhouses.

(3) Spray irrigation.

(4) Snowmelting, outdoor heating and wintertime street and road clearing.

(5) Fish farming.

(6) Area urban heating.

(7) Waste heat and low-pressure steam for various industrial purposes.

(8) Inducing better circulation in certain lake regions.

Presently, the most viable waste-heat disposal method is to put it into the air. If the air is used for heat dispersion, localized atmospheric heating could become a problem, particularly if the plant were located near centers of population(69). The disruptive effects resulting from dumping massive quantities of heat directly into the atmosphere are not believed to be as great as putting it into a lake or river. In the next century, however if the present forms of energy production and associated thermal pollution continue to increase, significant changes in climate are believed possible.

Various disposal methods are available, including direct, air-cooled condensers, cooling ponds and cooling towers. In addition, there are several type of cooling towers and several ways to operate the resulting system. Space does not permit a detailed discussion, but Table XIV indicates some of the costs associated with various control measures for

TABLE XIV

COMPARATIVE COSTS OF COOLING WATER SYSTEMS FOR STEAM ELECTRIC PLANTS

Type of System	Investment Cost for a 1,000 Megawatt Plant: Fossil Fuel	Investment Cost for a 1,000 Megawatt Plant: Nuclear Fuel	Increase in Operating Cost Mills/kwh
Once-through, no control measures, heat discharged directly into a fresh water river or lake	This method taken as base-line--it is the minimum cost option and requires no additional costs		
Cooling ponds with recirculation of the water from the pond (approximately 1,000 acres needed for a plant of this size)	$4 to 6 million	$6 to 9 million	0
Wet cooling towers, most heat loss to atmosphere via evaporation with resultant production of fogs, mists, and considerable water loss	$5 to 9 million	$8 to 13 million	Forced Draft 0.0771 Natural Draft 0.0211
Dry cooling towers, heat transferred to atmosphere without evaporation, no resulting fog or mist. To date no such towers have been constructed for a large power station	perhaps $20 million	perhaps $25 million	0.0937

thermal wastes. Cooling ponds or lagoons require sizable land areas, up to one acre per MW of installed generation capacity.

Natural-draft cooling towers as seen in Figure 9 are presently the most popular alternative. In these "wet" towers, the heated water mixes with air and is cooled largely by evaporation, resulting in a substantial quantity of water being lost to the atmosphere.

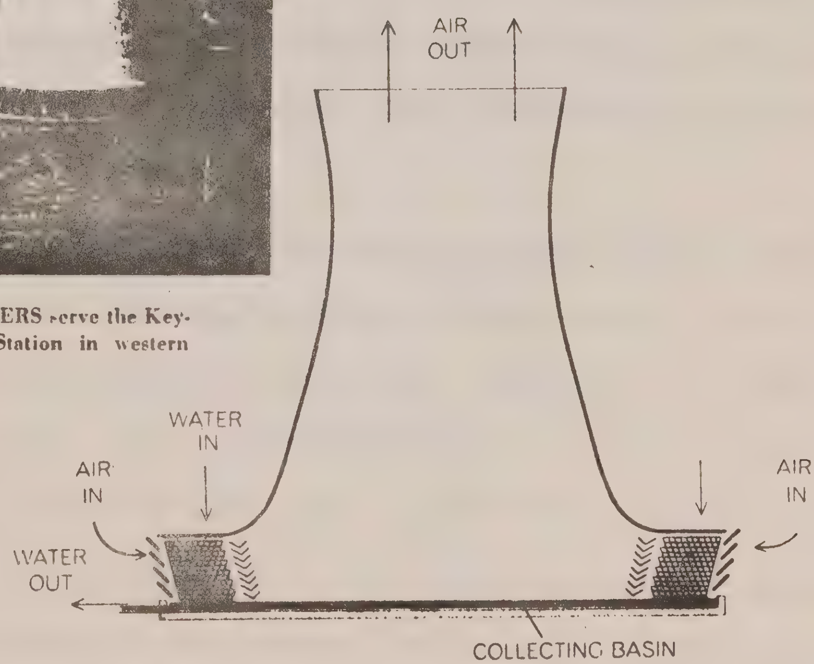
In Ontario, the environmental effect of giant-size cooling towers might be expected to be more significant than elsewhere because of lengthy periods of freezing weather during the winter time. Icing of the roads and a reduced visibility, because of stable fog conditions caused by moist warm plumes hitting the ground, has caused concern and raised questions about the environmental impact of this cooling alternative.

Updated air-quality regulations forthcoming from the Department of the Environment will place an emission limit on water vapor such that a 30 minute average at the point of impingement for a receptor may not exceed 0.25 grams of water vapor per cubic meter. This limit is imposed to prevent fogging and/or icing from man-made water vapor sources.

One hyperbolic tower 500 feet high, 300 feet exit diameter and with a 300 feet base diameter was assumed for a 1000 MW power station. Plume rise and dispersion calculations were made for (a) a single tower and (b) three towers in a row (a 3000 MW plant) by the methods specified in the regulations. Assuming an exit speed of 20 ft./sec. with an ambient air temperature of 20^{o}F and wind speeds from 15 to 25 miles per hour, some increase in the water-vapor concentrations at ground level or up to 200 feet above ground level was found[70]. However, even for rela-

FIGURE 9

FOUR COOLING TOWERS serve the Keystone Steam Electric Station in western Pennsylvania.



tively improbable weather conditions the water-vapour concentration derived from such cooling towers should not exceed 0.05 grams/cubic meter on the ground and up to 200 feet above the ground, for a distance up to 13 miles away from the tower. Consequently, it appears that this cooling concept will not cause ground-fog formations or icing of the roads, provided that no downwash occurs in the wake of these hyperbolic towers. Others who have examined this problem have also arrived at the same conclusion[71,72].

The plume-rise equations employed are not rigorously valid for extremely moist plumes. Moreover, model tests have shown that aerodynamic flow disturbance behind the tower can, under certain wind conditions, produce a downwash causing the plume to touch down a few tower heights away and deposit water on the ground. A buffer zone of perhaps 1 mile, around evaporative cooling towers, could prevent a local reduction of visibility and ground icing on public property.

Although the preliminary analysis[70] indicates, that this cooling method will probably, in the next two decades, result in lower overall environmental impact than putting waste heat into water, more work in this area is needed. In particular, the flow characteristics of the plume in the wake of arrangements of several towers must be determined.

Also, it should be noted that when wet cooling towers are used for fossil-fuel plants, the SO_2 emissions may interact with the water forming sulfuric acid mists. Obviously such situations should be avoided.

"Dry" cooling towers which contain a closed-circuit,cooling-water systems,

would resemble giant automotive radiators. They eliminate some of the problems of wet towers outlined above. The clear advantage of the dry-type cooling tower, over all the other cooling devices, is its independence of large bodies of water. It would permit consideration of many more potentially attractive sites and would reduce the demand for highly valued land adjacent to water bodies. Its major disadvantage is its high cost as shown in Table XIV, and it is not yet technically possible.

(d) IMPACT ON LAND USE

It is forecast that by the year 2000 the population of Ontario will increase to approximately 12 million, of which 80% will be urban dwellers. With an ever-increasing urban population, demands on the land, air and water will become greater. Because of the lack of foresight and ever-increasing pressure for economic and physical "growth", land-use patterns have emerged that are proving to be an environmental quality problem.

Hydroelectric Power Generation

Dams and reservoirs affect water quality through thermal changes and interruption of the natural patterns of stream discharge.

The physical changes resulting from hydroelectric-power production affect fish production by preventing migration to spawning beds and causing fish kills. Spawning and nursery habitats are destroyed or changed. Waste entering the water from construction sites affect the chemical and physical properties of downstream habitat. New species of aquatic life can be introduced into receiving waters disrupting fish communities and introducing new diseases and parasites.

Stream regulation and diversion for the generation of power must be compatible with existing downstream water uses, nor should flow regulation inhibit downstream development by denying the water resources to downstream users. In no instance should the river flow be reduced or fluctuate to such an extent that water-quality impairment exists downstream as a result of existing uses. This has occurred to some extent on the Madawaska River.

Low-water levels can limit recreational use, decrease shoreline property value and jeopardize aquatic biota. In addition, the fluctuating flow, combined with higher than normal peak flow rates during periods of maximum power generation, contributes greatly to increased erosion rates of the stream bed. The higher sediment loads carried by such streams impair the quality of water for potable use and consequently increase the costs of treatment.

It is also possible for diversion of flow through hydroelectric generators to decrease substantially the desirability of a waterfall as a tourist attraction. Niagara Falls, for example, is one case where the requirements of tourism have dictated that a minimum streamflow over the Falls be maintained. Kakabeka Falls on the Kaministikwia River near Thunder Bay has not fared as well. This Falls, once one of the finest natural atrractions in the area, has been reduced to a fraction of its normal flow because of the diversion of the water for power generation.

Both in the operation of existing hydro generation plants and in the planning of new possible hydroelectric facilities, it is recommended that decisions affecting the following areas be carefully co-ordinated between

cognizant government departments;

(a) Effects of water-level fluctuations on flora and fauna, shoreline erosion, timber production, and recreational use upstream and downstream from dams.

(b) Effects of dams, diversions, etc., on the aquatic environment.

(c) Details of land clearing for impoundments.

Furthermore, it is recommended that in these operations;

(a) A biological investigation is a prerequisite for any feasibility study undertaken for future hydroelectric power development. Furthermore, long-term studies are necessary to investigate future water needs and potential of major diversions.

(b) Land should be purchased and managed for public access, boat-launching, shore fishing and other facilities within the reservoir and upstream, and when practical, reservoir levels should be maintained for optimal recreational benefits.

(c) Flows should be maintained to ensure upstream migrations and spawning and culture of fish in downstream waters. When spawning habitat is lost, stocking and spawning channels be provided.

(d) Water quality should be maintained during construction and clear-cutting to above floodwaters and removal of timber should be made in every reservoir, to accepted standards.

(e) The losses and impact to Indian bands, whose heritage and way-of-life depend upon the waters, be minimized.

Routing of Transmission Lines

Approximately 100 acres are required for one mile of transmission lines; the farther away an electric station is from the consumers of power, the

more land is removed from other uses. Yet, the closer a power plant is to consumers, the greater the chances of harmful exposure of large numbers of people to the various pollutants produced by these plants.

Most of the environmental factors suggest that the generation plant is best removed from the population centers, at least until several of the pollution techniques discussed previously can be practically applied. Nevertheless, the aesthetic senses of increasing numbers of people are offended by transmission lines and certain other environmentally questionable practices in maintaining them.

Ontario Hydro appears committed to construct new rights-of-way in Southern Ontario in such a way that they will have the minimum impact on the surrounding topography. However, it is reported that separate (less strict) procedures will be issued for Northern Ontario. It is suggested that the policy adopted for Southern Ontario be extended to areas of Northern Ontario in the vicinity of present and possible future populated areas, and areas having present or future recreational and aesthetic values.

The use of herbicides and defoliants in clearing and maintaining transmission line rights-of-way has been questioned by several conservation groups and individuals in briefs to Task Force Hydro. The Ontario Pesticide Advisory Committee was requested to investigate this practice. They conclude[73] the current practices of Ontario Hydro, the type of herbicide used, the applied concentration and method should not lead to future difficulties. Their report suggests that public groups be fully informed of the practices and invited to accompany the spraying teams.

It should be noted that other types of ground-cover can be planted and used for weed control purposes. This approach should be encouraged.

In summary, the following recommendations are made with respect to transmission line routing and procedures:

(a) Begin development of techniques directed toward the future replacement of some transmission lines with underground cables.

(b) Intensify studies on multiple use and to utilize rights-of-way for recreational purposes. Accelerate on-going studies on how to obtain additional multiple use values from transmission lines by establishing and maintaining low cover for wildlife habitat and food.

(c) Intensify studies to maintain or improve the aesthetic values related with installations themselves and field operations by sculpturing, visual screening, etc. Where at all feasible, lines overhead of water should be replaced by submarine cables.

(d) Study the problem of transmission line location in the agricultural areas of Southern and Northern Ontario with the objective of minimizing the destruction of woods and trees.

(e) Proposed routes be discussed with regional and urban planners and the public at an early stage, so that the selected design and route may be compatible with designated zone uses and public desires.

(f) Environmental impact statements be prepared and be co-ordinated with other departments and the public for the routing and planning of transmission lines.

Solid Waste Disposal

The disposal of ash waste materials, mostly from coal-burning plants presents little problem in terms of utilizing this material in controlled landfill sites. The product is relatively inert, poses little leachate problem, can be easily handled and spread on the site and when covered with approximately two feet of top soil and sodded, can be used almost immediately for limited recreational purposes.

Some preliminary research has been done using fly-ash as a filler material for road foundations and also as an aggregate for cinder-block construction and undoubtedly additional uses can be found for this product in the future[74].

Radioactive waste is also regulated at the federal level. Originally, the philosophy of radioactive-waste disposal was to have all material buried in one controlled site on crown land so that control in perpetuity could be effected. Since the inception of radioactive-waste disposal, data collected with respect to on-site safety techniques, migration of radioactive products and general control of the site indicate now that other sites may be considered for this purpose.

Liquid radioactive wastes can be processed in a number of ways to reduce the amount of radiation to a point where secondary methods of disposal can be employed. Some of these methods would include;

(a) chemical precipitation

(b) ion exchange

(c) absorption

(d) dilution and discharge into sewers

(e) deep-well disposal

(f) combustion

It should be remembered however, that in each type of treatment, there will still be a solid-waste disposal problem associated due to the various by-products produced, process material and basic equipment, which will wear out over a period of time.

At present, it is very difficult to quantify this aspect of waste material associated with energy production, until firm figures are available with regard to percentages of energy produced by nuclear sources as compared to others.

Section IV

ENERGY AND THE LAW

(a) CURRENT LEGISLATION

Air Pollution

Province of Ontario

Ontario has enacted the most comprehensive air-pollution legislation in Canada. Control is exercised under the recently passed Environmental Protection Act[75], which also includes legislation for water, solid waste, noise and pesticide abatement and control. The Air Management Branch, part of the Department of the Environment, enforces the Act, through a set of air-pollution regulations.

Emission standards for some eighty contaminants are stated in terms of ground-level concentration at the point of impingement (½ hour average), for which the control system must be designed. In addition to the emission limitations, the general regulation also includes the desirable air quality for some 27 air pollutants. Specific regulations govern emissions from automobiles, asphalt plants and ferrous foundries. A sulfur content in fuel regulation is limited to Metropolitan Toronto.

An Air Pollution Index[76] system is in force in 4 areas, Metropolitan Toronto, Hamilton, Windsor and Sudbury. The Index is used to reduce harmful emissions, depending upon adverse meteorological conditions. The Index is a 24-hour running average of sulfur dioxide and solid particulate values and has been determined from past air-pollution episode conditions in other parts of the world.

Table XV compares air-quality objectives, which have been in effect in Ontario for several years, with the values recently announced by Environment Canada*and the Federal U.S. standards. Generally speaking, there are no significant differences between the three and thus, North America has rather uniform air-quality objectives and Ontario's programme is consistent with these goals.

Federal Government

In order to bring about uniformity across the country The Clean Air Act of 1971 (Bill C-224)[77] provides for agreements between the provinces and federal government. It could also provide for funding of provincial programmes operating to standards set by the federal government.

Federal installations, which have been exempt from provincial requirements, will be required to meet federal requirements. These may or may not be as stringent as the provincial requirements.

There is authority in the legislation to:

(1) set national air-quality objectives (Table XV)

(2) set national emission standards where the emission could cause a national health hazard, or to comply with the terms of an international agreement, such as those involved with trans-border pollution

(3) regulate the composition of fuels imported into or produced in Canada, and

(4) set national emission guidelines.

*Environment Canada is the federal department responsible for the administration of The Clean Air Act.

TABLE XV

NORTH AMERICAN AIR QUALITY OBJECTIVES

in mass units ($\mu g/m^3$)
with volume units (ppm) in brackets

	Federal Max. Desirable	Federal Max. Acceptable	U.S. Secondary	ONT. OBJECTIVES
Sulfur Dioxide				
1 hr	450 (0.17)	900 (0.34)	1300 (0.50)**	650 (0.25)
24 hr	150 (0.06)	300 (0.11)	260 (0.10)	260 (0.10)
1 yr	30 (0.01)	60 (0.02)	60 (0.02)	60 (0.02)
Particulates				
24 hr		120	150	120
1 yr***	60	70	60	60
Carbon Monoxide*				
1 hr	15 (13)	35 (30)	40 (35)	36 (30)
8 hr	6 (5)	15 (13)	10 (9)	16 (13)
Oxidants				
1 hr	100 (0.05)	160 (0.08)	160 (0.08)	200 (0.10)
24 hr	30 (0.015)	50 (0.025)		
1 yr	20 (0.01)	30 (0.015)		
Hydrocarbons				
3 hr		160 (0.24)	160 (0.24)	None

* mg/m^3

** 3 hr. max.

*** geometric mean

Water Pollution

A detailed discussion of the legislation relating to water legislation is contained in a discussion by Henry Landis, Q.C. entitled "Legal Controls of Pollution in the Great Lakes Basin", The Canadian Bar Review, March 1970 pp 66 to 157. Many of the following sections are direct quotes from this reference.

Province of Ontario

(a) <u>The Ontario Water Resources Commission Act</u>[78]

The Ontario Water Resources Commission was established as an agent of the Crown in right of Ontario in 1956 by the Ontario Water Resources Commission Act. The Act provides that the Commission may examine any surface or groundwaters in Ontario to determine what, if any, pollution exists and the causes thereof, and empowers the Commission subject to the approval of the Lieutenant Governor in Council to make regulations prescribing standards of quality for sewage- and industrial-waste effluents and for receiving waters.

No regulations have yet been made prescribing standards of quality for waste effluents and for receiving waters. The Commission published objectives in June 1967 which were updated in "Guidelines and Criteria for Water Quality Management in Ontario, June 1970[78]". These objectives do not have the force of law. However, the Ontario Water Resources Commission Act provides many legal controls, which may be used to secure compliance with them, for the purpose of the prevention and control of pollution of waters.

The quality of water must be related to the uses made or proposed to be made of the water. Since Section 27 of the Act does not refer to the quality of water for any particular use, the courts have proceeded on the principle that the ability or potential of the material discharged to impair the quality of the water for any of the uses, for which it was suitable at the time of the discharge, is sufficient for an offence.

The Act empowers the Commission to apply to a court, without notice to any person who may be affected, for an order limited in the first instance to a period of twenty-one days, to prohibit the discharge or deposit of any material into or near any well, lake, river, pond, spring, stream, reservoir or other body of water or watercourse that, in the opinion of the Commission, may impair the quality of the water.

(b) The Municipal and Public Parks Act

Under the provisions of The Municipal Act all municipalities may pass by-laws, inter alia, for preserving shores, bays, harbours, rivers and waters and the banks thereof, for prohibiting the injuring, fouling, filling up or encumbering of such areas or waters. If the municipal by-law encroached on a field within exclusive federal jurisdiction or if there was such a conflict or if it was otherwise within an occupied legislative field, it would be invalid.

The Public Parks Act makes it an offence for any person to thrown or to deposit an injurious or offensive matter into water, or upon ice in case the water is frozen, or to foul water in any reservoir, lake or pond in a public park in a municipality.

(c) The Public Health Act

Any polluted waters that are or may become injurious or dangerous to health or that prevent or hinder the suppression of disease are a nuisance and may be abated under The Public Health Act. Other provisions of the Act deal with the prohibition of pollution of waters.

(d) The Lakes and Rivers Improvement, Public Lands and the Provincial Parks Acts

These Acts contain numerous provisions and regulations although not expressly prohibiting pollution, can be applied to prevent or minimize it.

(e) The Environmental Protection Act(75)

This Act encompasses many of the provisions contained in other acts and contains provisions not previously legislated.

(f) Conservation Authorities Act

A conservation authority has power to control the flow of surface waters to prevent or reduce the adverse effects of pollution thereof for the conservation, restoration, development and management of natural resources.

Federal Government

(a) Navigable Waters Protection Act(79)

The federal jurisdiction in relation to navigation and shipping does not authorize legislation for control of waste inputs and enforcement of standards of quality for any other use of water than navigation and shipping.

(b) Inland Fisheries[80]

The exclusive federal jurisdiction in relation to Inland Fisheries authorizes legislation for the conservation of fish, such as legislation providing for enforcement of standards of water quality that promote this end, and for control of discharges into waters of waste inputs harmful to fish. Standards of quality for conservation of species of fish cannot easily be defined. Therefore, conservation of fish is too narrow a purpose of legislative jurisdiction to achieve the quality of water required for the maximum number and variety of uses specified in the Ontario Water Resources Commission Act.

(c) Indian Act

The exclusive federal jurisdiction in relation to Indians and Lands Reserved for the Indians authorizes legislation for the regulation of their lives and affairs on a reservation. Under the Act, the Governor in Council may make regulations and the council of a band of Indians may make by-laws not inconsistent with the Act or regulations thereunder, in relation to, inter alia, fish, noxious weeds and contagious and infectious diseases on reserves.

(d) Migratory Birds Convention Act

This Act prohibits pollution of waters frequented by migratory birds or waters flowing into such waters or the ice over such waters, by oil, oil wastes or substances harmful to migratory birds.

(e) Canada Water Act[81]

The following are highlights of the Canada Water Act:

(1) Together with the provinces, the federal government may designate, as a water-quality management area, any body of water where there is signficant national interest.

(2) Pollution of waters in such designated areas may be punishable by a fine of up to $5,000 for each offence.

(3) Together with the Provinces, or alone if necessary on inter-jurisdictional waters, the federal government may launch water-quality management programmes in designated problem areas.

(4) Water-quality management agencies may design and operate sewage treatment facilities, collecting charges for the treatment of wastes delivered to these facilities.

(5) Together with the provinces, the federal government may establish joint commissions, boards or other agencies to conduct water-management programmes. Such programmes would be concerned with the supply, quality, distribution and other aspects of water -- a comprehensive approach to multi-purpose water resource management.

Radioactive Emissions

The authority, in Canada, which controls all uses of radioactive materials including the operation of nuclear power stations is the Atomic Energy Control Board (AECB) assisted by the Reactor Safety Advisory

Committee (RSAC). The Reactor Safety Advisory Committee is specifically selected for each individual reactor and reviews with the Board's staff officers all aspects of the proposed station from preliminary concepts and proposed site through design and commissioning to routine operation. The RSAC consists of experts in many disciplines and representatives from other interested regulatory authorities. For a reactor to be sited in Ontario, the AMB, the OWRC, the Department of Labour, the Provincial Department of Health would be represented, along with the Medical Officer of Health for the County or areas adjacent to the reactor site.

(b) INTERNATIONAL PROGRAMMES

Fish throughout the world are becoming contaminated with mercury. Toxic metals and air pollutants are filtering across national boundaries. Many nations realize they need to upgrade their domestic environmental programmes. Other nations seek new comprehensive policymaking and administrative weapons to deal more effectively with environmental decay.

A great many international programmes have been created in the pursuit of uniform environmental goals or standards and joint action on common international pollution problems. Canada and Ontario participate in many of these programmes, but a bilateral programme with the U.S. is of particular interest. The United States and Canadian Governments are working together (1) to restore the quality of the Great Lakes -- a vital asset for a large segment of the population on both sides of the boundary and (2) reduce the transboundary flow of air pollutants.

Ministers of both countries agreed to set up a Joint Working Group to study

and evaluate the Great Lakes problem. The Group began to study ten major problem areas and by April 1971, issued a report containing its recommendations[26]. It urged the two Federal Governments to agree to adopt common water-quality objectives for the Great Lakes, to agree to programmes for attaining the objectives, and to give the IJC authority to monitor these efforts.

Subsequently, the two Governments agreed to adopt the report of the Joint Working Group and to complete a Great Lakes Water Quality Agreement embodying the recommendations by the end of the year. The agreement will specify measures to control Great Lakes pollution by 1975, which may include regulations regarding thermal-waste disposal.

The International Joint Commission has also been active in the evaluation of joint air-pollution problems[82]. Recently, the Air Pollution Control Office of the U.S. Environmental Protection Agency issued a set of proposed standards. These standards are slightly higher than those already adopted by Ontario. At this time, Ontario will continue to use the lower values and develop abatement strategies to meet the more stringent objectives.

Air pollution in the Windsor-Detroit and Sarnia-Port Huron areas has caused concern for many years. The International Joint Commission, at the request of both governments, has carried out comprehensive investigations of the inter-boundary flow of air pollutants which is reported in Reference 82. The study recommended that control agencies, in both countries, accelerate their abatement programmes to bring all sources into compliance with the law. Costs for control of SO_2 and particulate matter only in these two areas was estimated at over $65 million. A committee composed of the

heads of the air-pollution control programmes for the State of Michigan, Wayne County and the Province of Ontario has been established to achieve these goals.

Although the IJC programme is active, it is probably fair to summarize it by saying that progress in the form of remedial action is slow in coming. The U.S. government has not yet provided its share of resources needed to carry out the recommended programme.

(c) PROPOSED FUTURE LEGISLATION

Province of Ontario

New expanded regulations are being issued in the Environmental Protection Act, 1971 which covers the emission of many more pollutants. None of these will further impact the energy industry. At present, Ontario has no reactive hydrocarbon emission standard (reactive hydrocarbons are the species which may produce photochemical smog). Either a provincial or federal standard seems likely sometime in the future and this could affect the refining industry and automotive emissions.

The new Act also specifies community noise as an environmental pollutant, but the energy industry has no significant noise problems. Although it may limit the noise levels of devices which require energy (vehicles, air conditioners, mowers, snowmobiles, motorcycles, etc.), these regulations should not greatly impact the energy industry or significantly alter energy consumption patterns.

Segments of the OWRC have joined the Department of the Environment. It is possible, therefore, that the relevant legislation, namely the Environmental Protection Act and the OWRC Act[83] as they pertain to water pollu-

tion will be revised and consolidated into an expanded version of the Environmental Protection Act. It is not expected, however, that the basic programme as it is currently being conducted by the OWRC will change significantly. In addition, the new proposed Lakes and Rivers Improvement Act which has been submitted, but not proclaimed, will have a significant impact on the future uses of water in Ontario.

The purpose of this Act is to provide for the use of waters of the lakes and rivers of Ontario and to regulate improvements in them. It is proposed that;

(a) the preservation and equitable exercise of public rights in or over such waters;

(b) the protection of the interests of the riparian owners;

(c) the use, management and perpetuation of the fish, wildlife and other natural resources dependent on such waters;

(d) the preservation of the natural amenities of such waters and on the shores and banks thereof; and

(e) ensuring the suitability of the location and nature of improvements in such waters, including their efficient and safe maintenance and operation.

This Act may provide a means of declaring designated rivers as spawning and rearing grounds for migratory fish and to be kept free of dams,

- also for opening dams during spawning period on important trout streams,
- also restricting timber driving,
- also declaring rivers overloaded with works and prohibiting further works.

It is of interest to note that Ontario Hydro may not be taken to court without approval of the Ontario Attorney General at the present time. There may be public pressure to alter this situation in the future.

Federal Government

There have been considerable changes in air pollution control legislation during the past two years in Canada, at both the provincial and federal levels. With the entry of the Federal Government into the field in 1971, it is likely that additional changes will take place over the next few years, particularly in those provinces where control activities have been at a low level. Ontario may see these changes in terms of high costs of energy resources imported from other provinces.

The Federal Environmental Minister currently is contemplating two new bills[84]:

(1) Legislation to provide for loans to industries which are hard-pressed to meet federal and provincial air and water anti-pollution standards. Preference would be given to older plants having difficulty obtaining finances through other channels.

(2) Legislation to allow the new department (called Environment Canada) to screen new processes and products for damaging effects before they reach the market.

Other Legislation in North America

There are a myriad of air, water and radiation pollution regulations in the United States. Only some of the emerging trends pertaining to energy use are discussed here.

(a) Environmental Impact Statements[85] are a new ingredient in the U.S. They require that any group or agency of the U.S. federal government, proposing legislation or planning to undertake an action "significantly affecting the quality of the human environment", must file an impact statement. The statements must describe the legislation or action, its impact, and the alternatives considered. Before filing, the statements must be circulated by that agency to the public and to appropriate Federal, State and local environmental agencies. Comments received on the draft statement become a part of the public record. The Administrator of EPA has the independent responsibility for reviewing and commenting on the environmental impact of all proposed Federal activities or legislation.

Over 20 U.S. federal agencies have established internal procedures for preparing impact statements. Some agencies, for the first time, have explicitly incorporated environmental considerations into their decisions.

The system is not yet working as intended. Lack of environmentally-trained personnel and the difficulty of changing established decision-making patterns are still problems. Too often, the environmental statement is written to justify decisions already made, rather than to provide a mechanism for critical review. Consideration of alternatives is often inadequate, and the ultimate alternative i.e. "taking no action at all because of the environment" has rarely been considered. There is also the difficulty of any group in engaging in public self-criticism.

The value and completeness of these statements varies drastically from agency to agency. Some have been severely criticized as superficial, incomplete, incompetent and misleading. At the other extreme, the U.S.

Department of the Interior[86] has adopted an elaborate procedure calling for consideration of about 10,000 items in completing a 100 by 100 matrix and assessments must be made for any area, in which there is an environmental impact.

Although the requirement for environmental impact statements, which are made public, has its shortcomings, the basic idea is felt to be good. Various organizations of the Ontario government now use or advocate this concept in one form or another. It is strongly suggested that Ontario establish a policy of requiring environmental impact statements to be completed and evaluated by all Departments before new programmes are implemented. The approach adopted, should profit from the initial shortcomings of the U.S. programme and could be employed by all Ontario government organizations uniformly. It should not be restricted to assessment of the impact of energy use, but applied to all activities which affect environmental quality.

(b) Power Plant Siting legislation has also been recently proposed. Under the proposed legislation in the U.S., federal government decision-making on siting of power plants (exceeding 300 MW capacity) would be vested in State and/or regional site certification agencies[87]. In the absence of such an agency, or when it fails to act or resolve local differences, the proposed bill would put the final decision in the hands of an ad hoc 3-man arbitration panel, which would have strong siting approval powers, including modifying environmental regulations.

Also included in the proposed legislation, the utilities would be required

to identify and upgrade, annually, their regional expansion plans 10 years in advance of, and the plans for specific sites 5 years prior to construction. These plans should include a site inventory, as well as environmental impact statements for each site. Two years before construction is to start, the utilities would be required to submit a detailed proposal and an environmental review for the site.

The intention of these long-time intervals between planning and construction is to provide plenty of time for the public and other agencies to assess the proposed plans and to avoid costly last-minute court fights.

This proposed legislation has been apparently directed to cure problems of a system, that does not exist in Ontario -- the existence of a great many privately-owned companies and a few publicly-owned companies, a wide variety of state siting legislation, increasing public pressure to have a voice in siting and a federal government trying to fill voids, left by some states and desiring a uniform national policy. Nevertheless, some aspects of this legislation might be incorporated in the future planning activities of Ontario Hydro.

Best of all, the legislation provides a forum where interdisciplinary representatives from responsible government agencies, must evaluate their parochial departmental interests against the public need, explore the alternatives, and arrive at the best informed decision. An initial step in this direction has been taken by establishing a Siting Task Force and working in close cooperation with other government agencies.

The experiment of the private utilities in sharing their fact-finding and decision-making processes with the public has been met with varying degrees

of acceptance. The experience of Northern States Power Company is especially encouraging. It serves to show that the public (consumers and conservationists) can work constructively and with an open mind in helping the utility in siting its power plants.

(c) Power Plant Emission Limits have recently been established by EPA in the U.S.[88]. All new electrical generating plants with over 250 million Btu/hr heat input will not be allowed to emit pollutants in excess of the following;

Solid Particulate Matter (Dust and Fly-ash)	0.10 lbs/million Btu input
Sulfur Dioxide	0.80 (oil) or 1.2 (coal) lbs/million Btu input
Oxides of Nitrogen	0.20 (gas) or 0.30 (oil) or 0.70 (coal) lbs/million Btu

The existing coal-fired Ontario Hydro plants could not achieve the SO_2 limit without using coal with a lower sulfur content then is presently being used. Limits such as these will not ensure improved air quality in the long-term, because the total imposed pollutant burden will continue to increase as additional plants are added.

Recently, California has adopted a new and more restrictive regulation for the emission of the oxides of nitrogen[89].

(d) State of California - Rule 68

"A person shall not discharge into the atmosphere from any non-mobile fuel-burning article, machine, equipment or other contrivance, having a maximum heat input rate of more than 1775 million British Thermal Units (Btu) per hour (gross), flue gas having a

concentration of nitrogen oxides, calculated as nitrogen dioxide (NO_2) at 3% oxygen, in excess of that shown in the following table."

Nitrogen Oxides
Parts per million parts of flue gas

Fuel	Effective date	
	December 31, 1971	December 31, 1974
Gas	225	125
Liquid or solid	325	225

The 1974 limits will require NO_X control measures at least in the form of combustion modifications. It seems relatively certain that such measures will spread across the U.S. and perhaps into Canada in the next decade. The present Hydro plants emit about twice this concentration of NO_X.

(e) Sulfur Emission Taxes(90) have also been proposed by the EPA in the United States. The charge would be levied on sulfur emitted into the atmosphere from combustion or distillation of fossil fuels. To the extent that sulfur is removed from fuels, no payment of the charge would be required.

The funds generated by this charge would enable the U.S. Government to increase programmes to improve the quality of the environment with special emphasis on development of technology to reduce sulfur oxide emissions and programmes to develop adequate clean energy supplies. This measure is intended to provide, both the incentive for SO_2 abatement and the means for doing so(91).

This abatement strategy has less appeal in Ontario, because it would largely amount to the government (Department of the Environment) taxing itself (Ontario Hydro). It is more direct for the government to decide that SO_2 emissions are to be reduced and then do what is necessary to achieve this policy. Such a tax, however, might be a strong incentive for the further reduction of emission from industrial boilers.

Section V

PROJECTED ENVIRONMENTAL QUALITY - 1991

(a) AIR QUALITY

Air quality is not consistent across Ontario; there are large areas where air pollution is virtually non-existent, while in other areas with large populations and industrial development, it is a serious problem. A preliminary evaluation of the future air quality has been made by Angus[92]. Only a brief summary is given here. Consult Reference 92 for additional details.

To predict the air quality in 1991, it has been assumed that:

(1) the present centers of air pollution will continue to be the critical areas of air pollution in the future, and

(2) the Air Management Branch abatement programmes would prevent other areas approaching poorer air quality.

Five cities which typify different types of communities in Ontario were chosen for study as listed in Table XVI.

Table XVI

Population Projections

City	1971	1991
Toronto	2,436,127	3,595,694
London	230,704	328,525
Hamilton	492,651	742,586
Sarnia	74,512	110,470
Sudbury	130,477	191,806
Electric Power Capacity	12,160 MW	48,640 MW

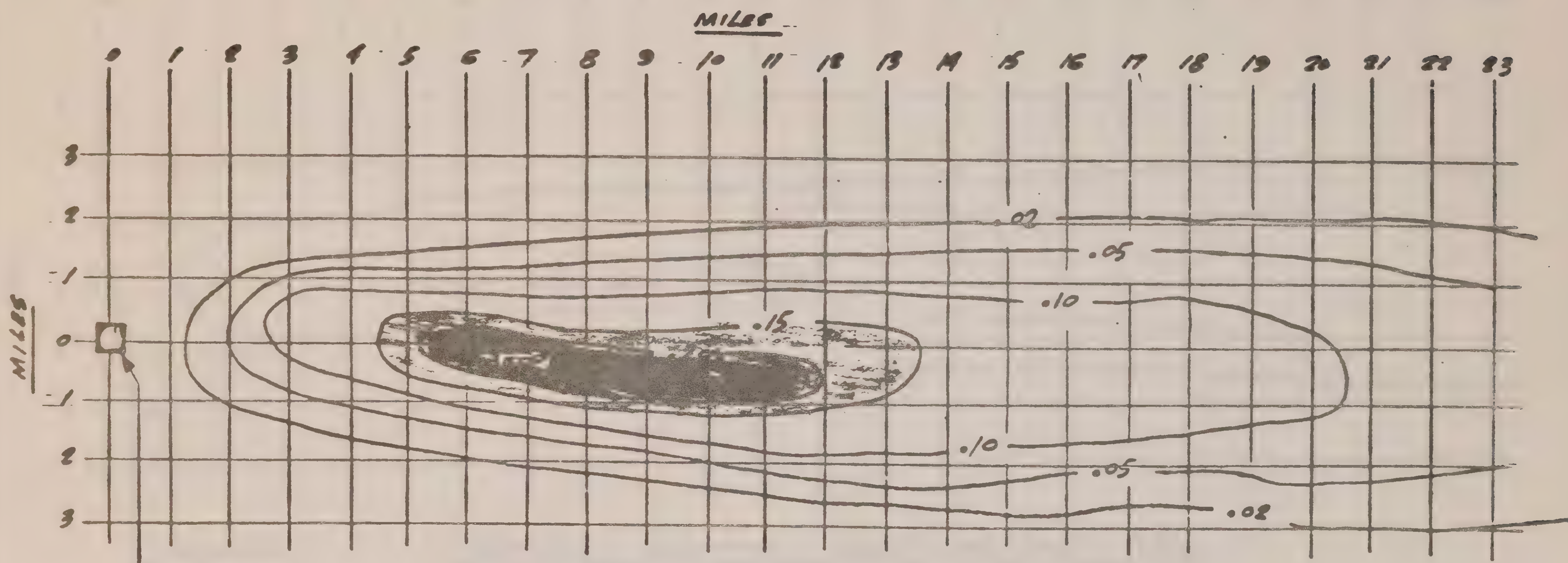
The air-quality criteria are listed below for those pollutants considered to give the best indication of overall air quality;

Criteria for Desirable Air Quality

Pollutant	Concentration 1 Hour	Annual Average
SO_2	0.25 ppm	0.02 ppm
NO_X	0.20 ppm	-
CO	30 ppm	-
Suspended Particulate	-	60 ugm/m^3

Calculated ground-level concentrations of SO_2, NO_X and solid particles, downwind from a hypothetical 6000 MW coal-fired plant, are shown in Figures 10, 11 and 12. These calculation were made, for an extremely large plant only, to illustrate a severe case which might conceivably occur in the future. Calculations were made for 1000 ft. high stacks, 2.5% sulfur coal and typical weather conditions. Although the predicted ambient SO_2 concentrations (Figure10) without a removal process, exceed the Regulations between 5 and 12 miles, with a 75% efficient SO_2 removal process (Figure 13) in operation, the ambient-air criteria would only be exceeded for a short distance around 6.5 miles from the station (compare Figures 10 and 13).

Air-quality problems may arise when such a plant is located in or near populated areas, which have other emission sources. There is always the desire to locate generation stations near the consumers, to reduce transmission losses and minimize land used in transmission line rights-of-way. Consequently, predictions of 1991 ambient air quality in three

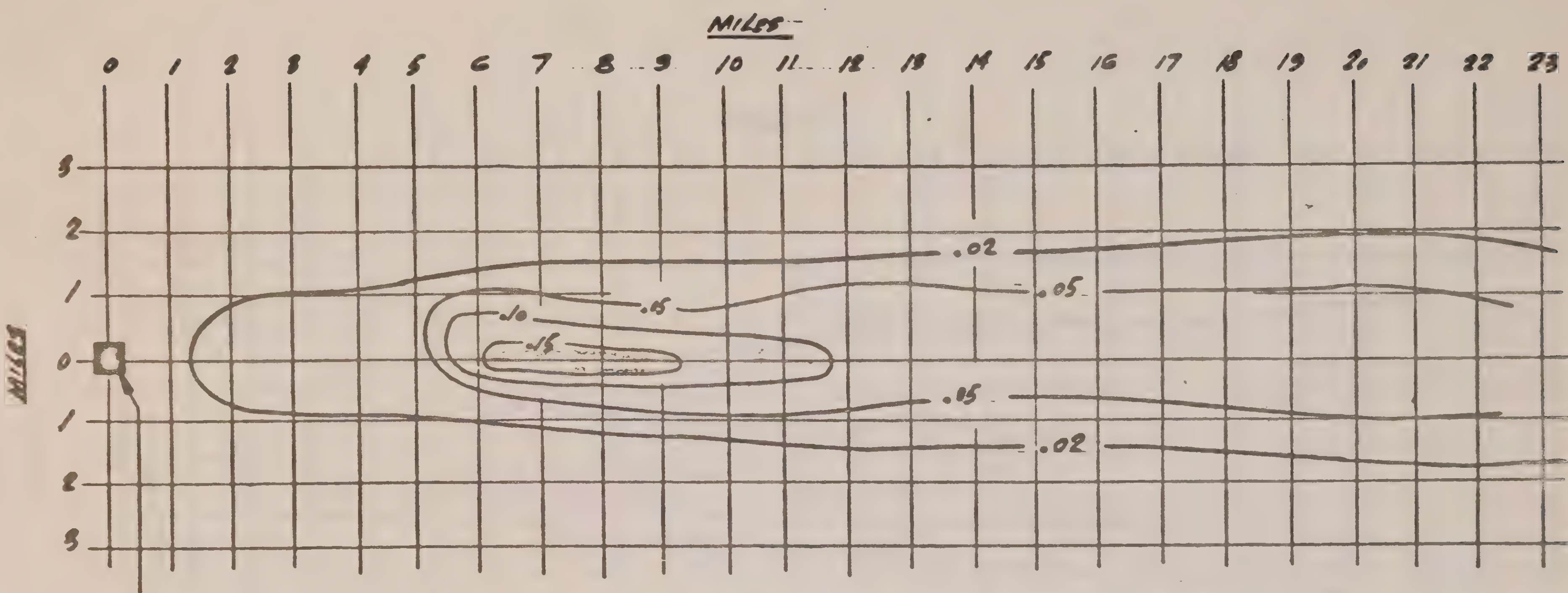


PREDICTED DOWNWIND CONCENTRATIONS SO_2

HOURLY AVERAGE P.P.M.

6,000 MEGAWATT POWER STATION
2 - 1000 FT. CHIMNEYS
FOSSIL FUEL.

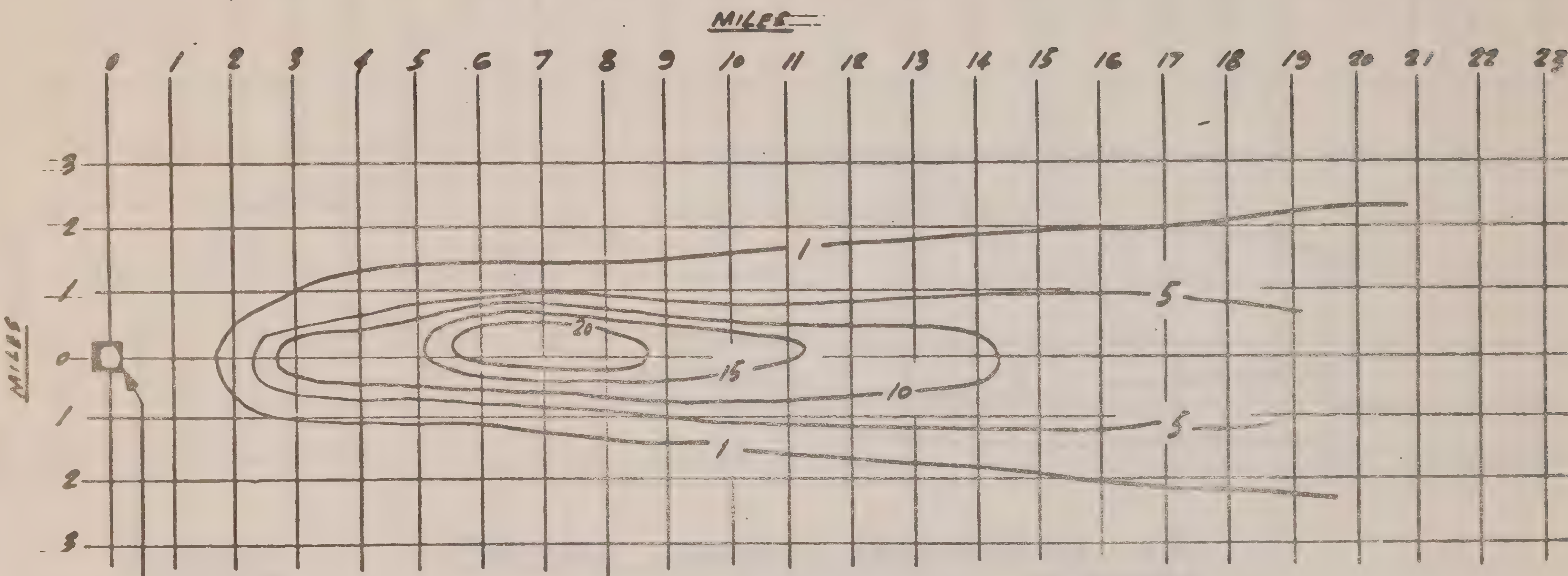
FIGURE 10



PREDICTED DOWNWIND CONCENTRATIONS NO_x
HOURLY AVERAGE P.P.M.

6,000 MEGAWATT POWER STATION
2 - 1000 FT. CHIMNEYS
- FOSSIL FUEL.

FIGURE 11



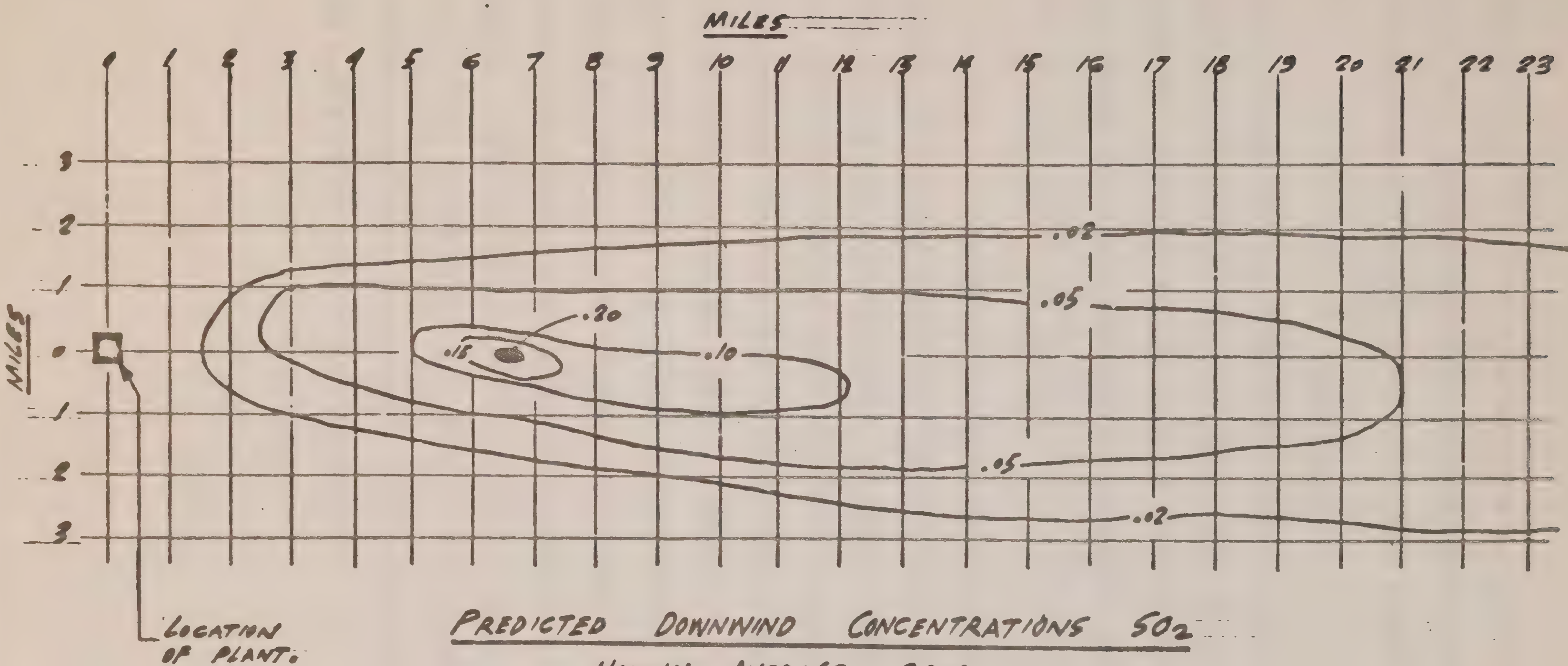
LOCATION OF PLANT

PREDICTED DOWNWIND CONCENTRATIONS PARTICULATES

HOURLY AVERAGE μg PER CU. METER

6,000 MEGAWATT POWER STATION
2 - 1000 FT. CHIMNEYS
FOSSIL FUEL.

FIGURE 12



PREDICTED DOWNWIND CONCENTRATIONS SO_2

HOURLY AVERAGE P.P.M.

6,000 MEGAWATT POWER STATION
2 - 1000 FT. CHIMNEYS.
FOSSIL FUEL
WITH 75 % SO_2 REMOVAL.

FIGURE 13

different types of regions have been made by adding fossil-fuel plant emissions to the projected emissions from other sources. In all cases a 75% SO_2 removal for power stations has been assumed.

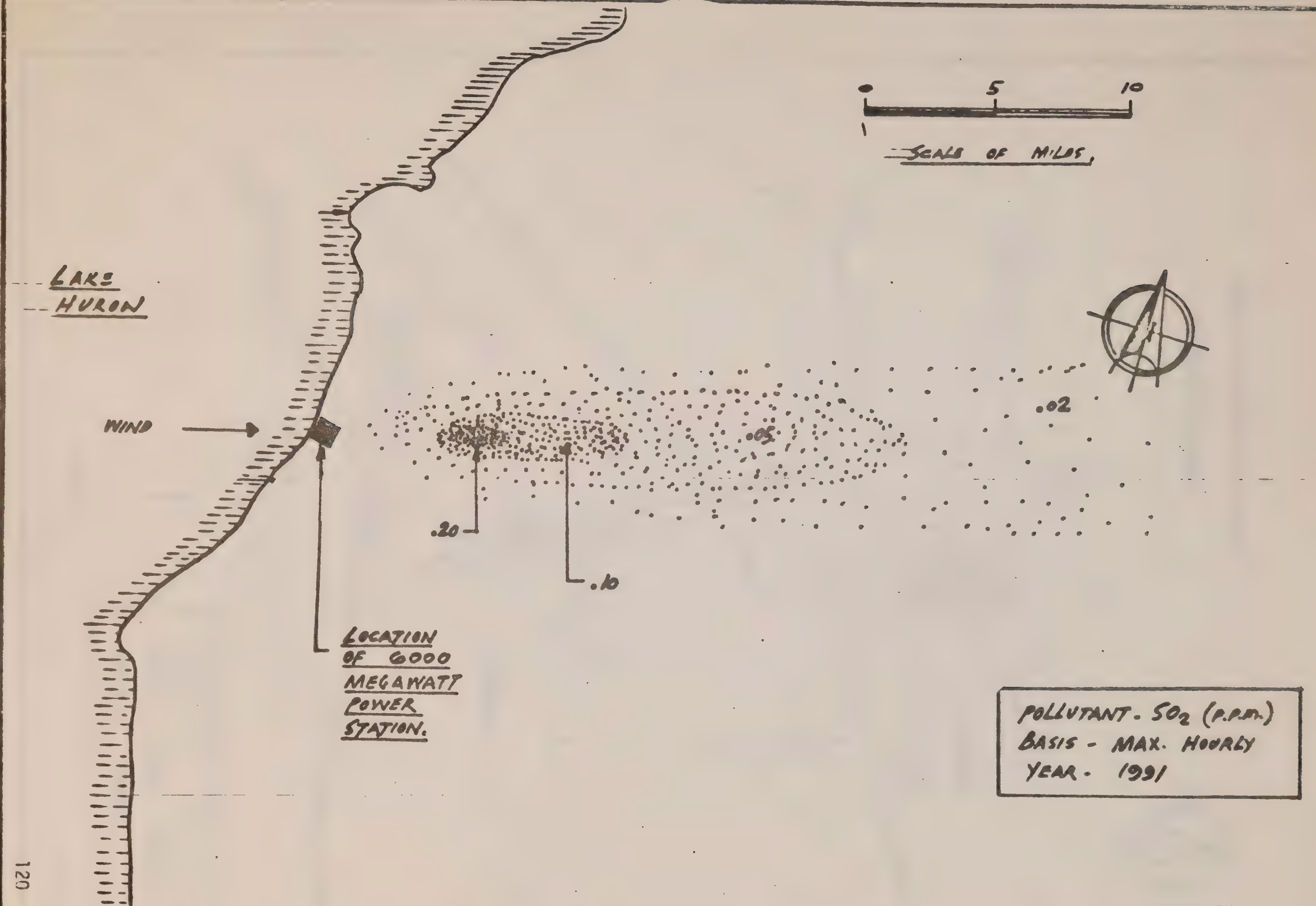
Rural Location

Figure 14 shows the SO_2 ground-level concentrations in a typical rural area for a hypothetical lake-front plant with 75% SO_2 removal. The concentrations shown also include those of small farming or rural communities and indicate that even large plants can operate within the present Regulations in isolated areas if SO_2 emissions are reduced, by some means, by 75%.

Locations Near Moderate-size Cities

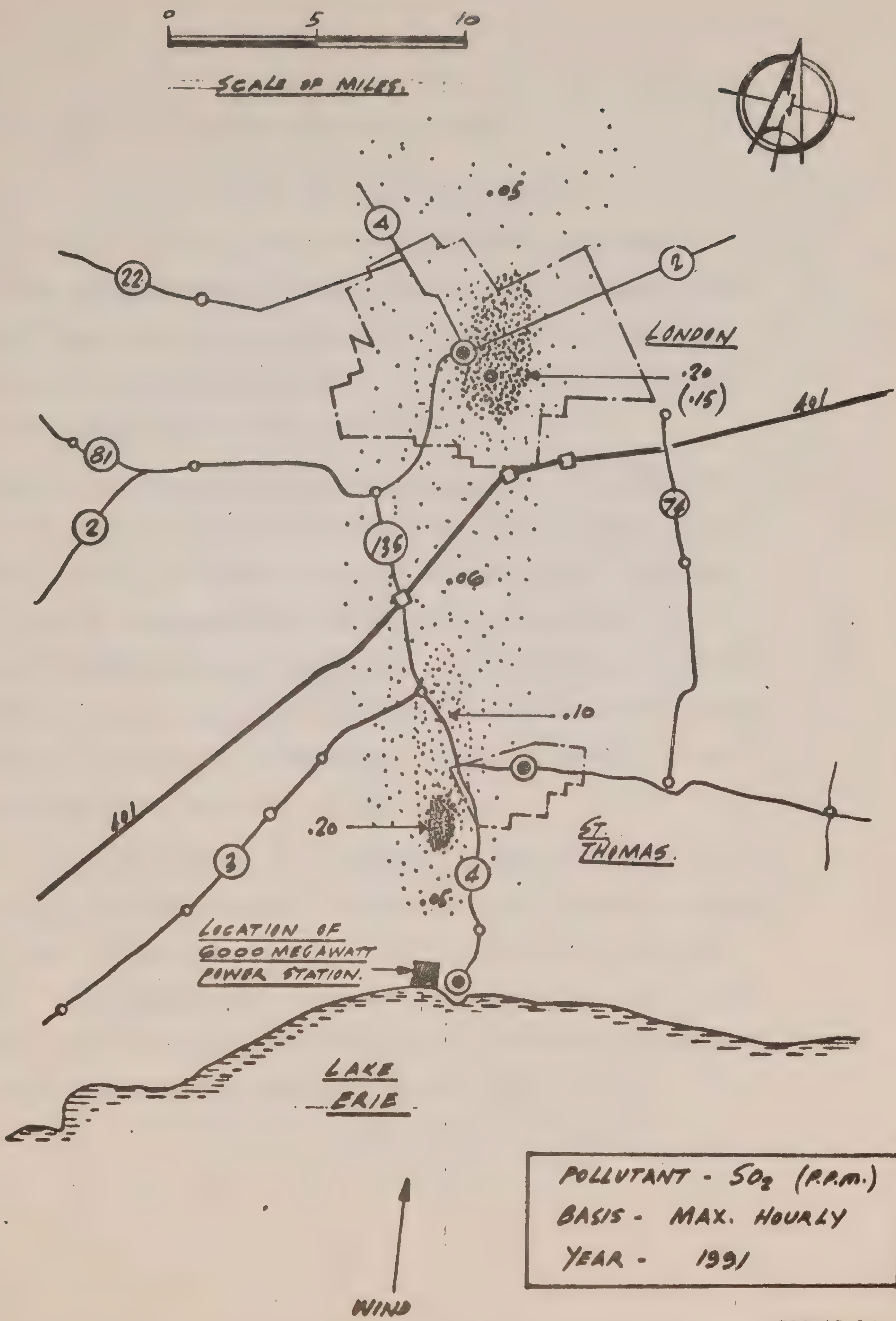
Figure 15 depicts the ground-level concentrations for a large hypothetical plant on Lake Erie somewhere south of London, Ontario. London is a sizeable center of population with little industry and the air quality in 1970 was quite good. Should a 6000 MW fossil-fuel generating station be constructed south of London on Lake Erie, then hourly concentrations of SO_2 would become marginal with respect to the criteria. The same would be true of St. Thomas or other similar small cities. The use of nuclear or smaller fossil-fuel plants would not be objectionable in this type of location. However, it must be concluded that large future coal-fired station sites should be at least 30 miles from moderate-size cities if the Regulations are not to be exceeded. It is particularly important to provide such a buffer zone in the vicinity of

1. Windsor
2. Sarnia



0
5
10
SCALE OF MILES,
LAKE
HURON
WIND
.02
.05
.20
.10
LOCATION
OF 6000
MEGAWATT
POWER
STATION.
POLLUTANT - SO_2 (P.P.M.)
BASIS - MAX. HOURLY
YEAR - 1991

FIGURE 14



0
5
10
SCALE OF MILES.
.05
4
22
2
LONDON
.20
(.15)
401
81
2
135
74
.06
.10
.20
401
3
ST. THOMAS.
4
.05
LOCATION OF
6000 MEGAWATT
POWER STATION.
LAKE
ERIE
POLLUTANT - SO_2 (P.P.M.)
BASIS - MAX. HOURLY
YEAR - 1991
WIND

FIGURE 15

3. Sudbury

4. Hamilton

which are areas with existing air quality problems.

Locations Near Very Large Urban Centers

The only area in Ontario by 1991 which is included in this category is the "Golden Horseshoe" region, Oshawa to Hamilton and including Toronto. The major impact upon the air quality in Toronto is made by the Hearn and the Lakeview generating stations. The contribution of pollutants from various major sources are as shown in Table II.

The generating stations have abatement programmes in effect now, while industrial emissions will be controlled in the future. However, the present air quality in Toronto due to SO_2 and particulates is marginal with respect to the Regulations (see Figure 16). Consequently, it is believed that the ambient air criteria will not be completely satisfied in 1991 with respect to SO_2 due to the overriding effect of the Lakeview generating station, unless extensive SO_2 abatement is carried out for it and/or many other sources in the Toronto area.

It is quite evident that the Toronto atmosphere cannot take the stress of additional emission imposed by expanded fossil-fuel generation capacity in the area. Ontario Hydro recognizes this and plans no expansion in Toronto. It is generally felt that additional fossil-fuel plants in the southern part of the Toronto Centered Region[93] should be avoided until SO_2 and NO_x emission control measures can be applied.

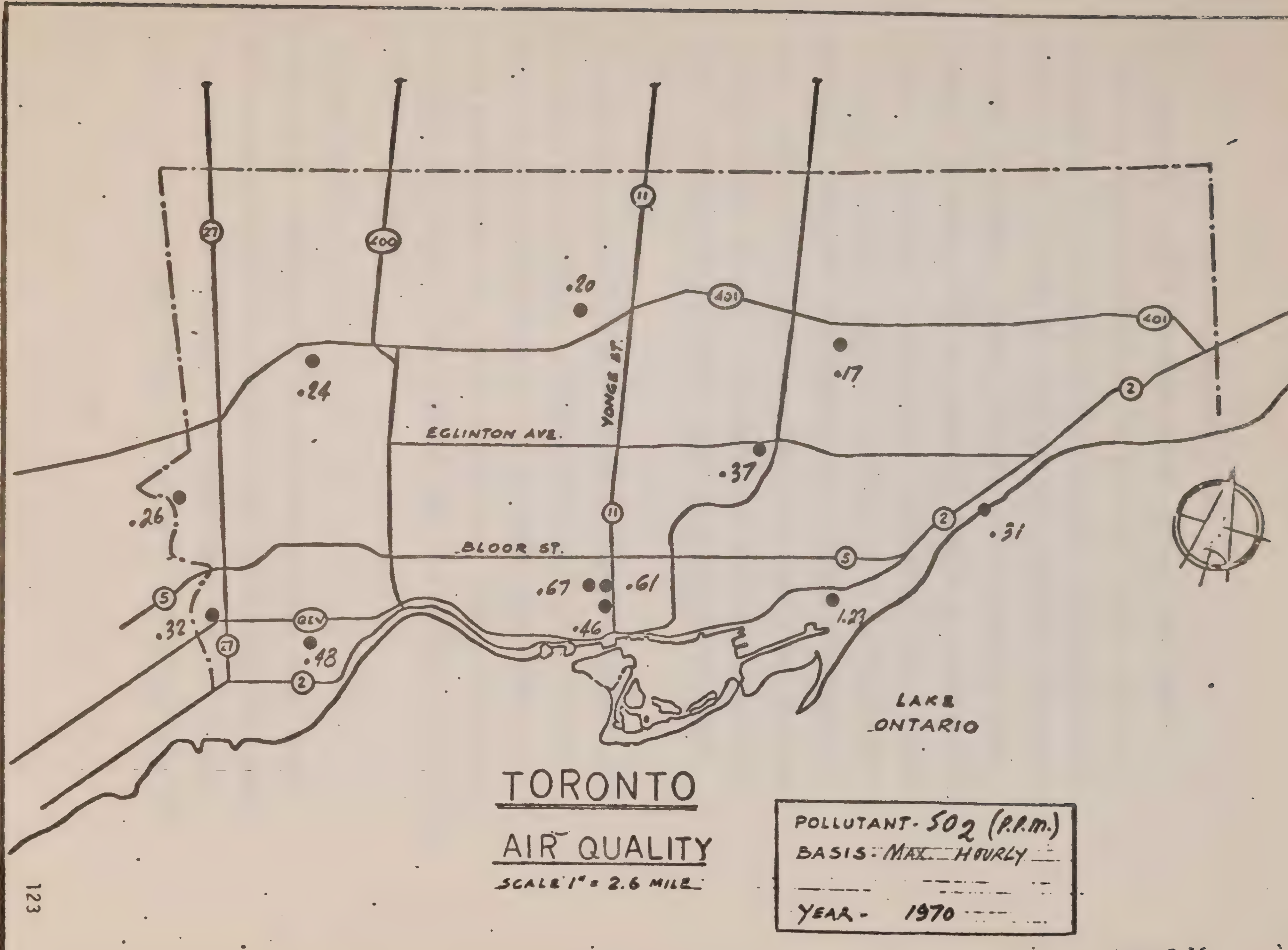

TORONTO
AIR QUALITY
SCALE 1" = 2.6 MILE
POLLUTANT - SO2 (P.P.M.)
BASIS: MAX. HOURLY
YEAR - 1970
LAKE ONTARIO
EGLINTON AVE.
BLOOR ST.
YONGE ST.
401
400
27
11
5
2
QEW
.20
.24
.17
.37
.26
.31
.67
.61
.46
1.23
.32
.48

FIGURE 16

Conclusions - 1991

It is concluded that the population growth, per se, is not alarming from an air pollution standpoint. The ambient-air quality, due solely to population will not exceed the Ontario criteria even when population density approaches 30,000 per square mile (equivalent to a high-density apartment development). However, the imposition of industrial growth, together with power-station development, will combine to produce concentrations of pollutants in excess of that recommended by Ontario Regulations, unless abatement is undertaken in future plants. The combination of people, industry and power generation will produce undesirable air-quality levels, and in future, good planning must ensure that this type of situation does not occur. Power-generation facilities, industry and dense population must be located so that a minimum of pollutant overlapping occurs.

Planning for the overall protection of the air quality in Ontario, must be given ongoing attention. Co-ordination of urban areas, industrial areas and power plant locations must be thoroughly investigated and adequate planning undertaken. There can be no other conclusion than that the future air quality in Ontario depends upon planning which is translated into effective action.

(b) WATER QUALITY

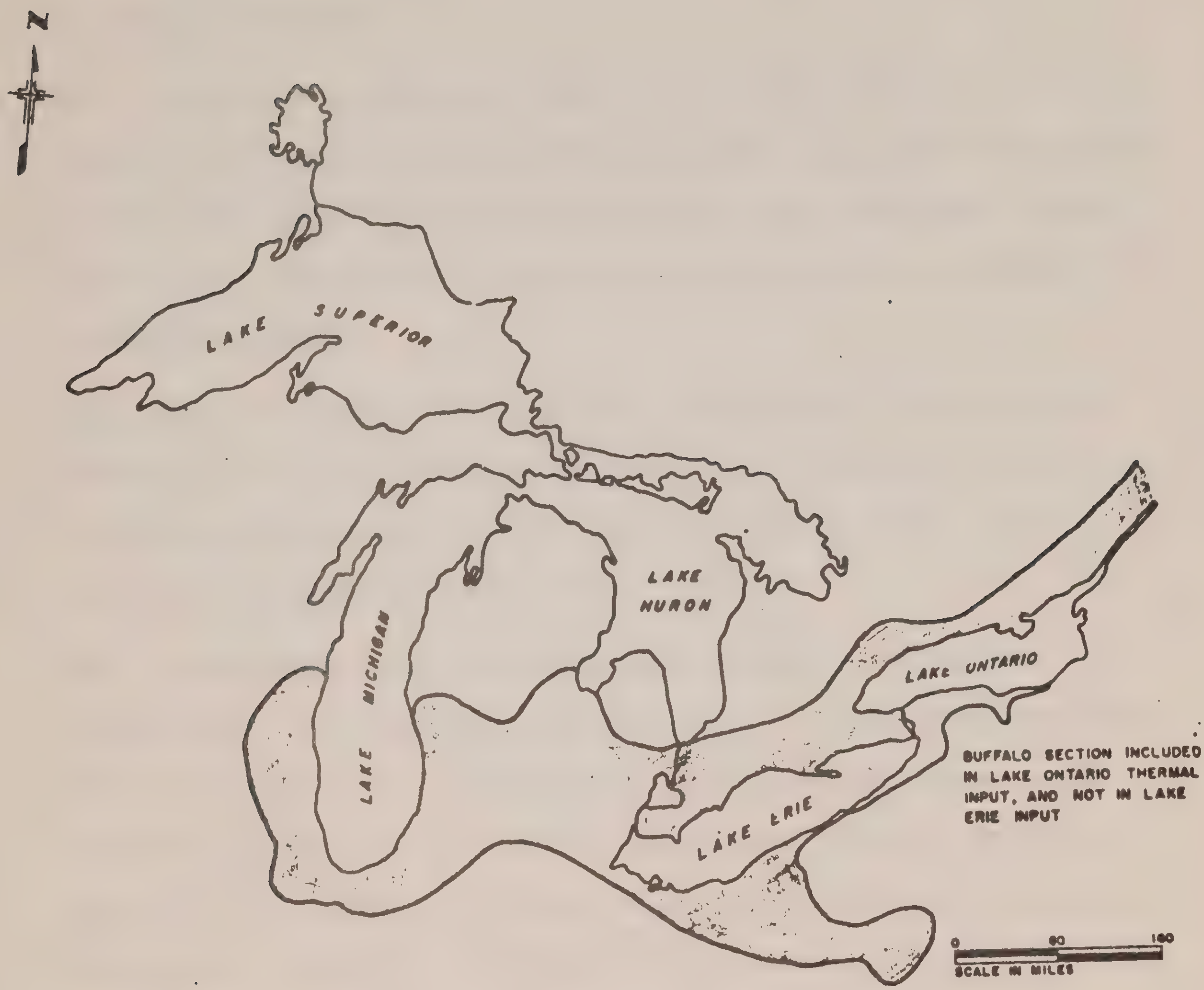
Because of the complexity of defining the overall quality of the aquatic environment, particularly the long-term effects, the OWRC does not attempt future projections of the impact of electrical power generation on water quality. The interactions of many different uses, which are not associated

directly with power production, affect water quality such that the Commission believes that each future power plant should be considered on its own merits.

Some estimates of the heat inputs to the Great Lakes to the year 2000 have been made by H.G. Acres Limited[61]. There are also some future water-quality projections in reports by the International Joint Commission[26]. While the long-term effects on a given lake, have yet to be adequately predicted, it is instructive to see the relative amounts of waste heat being added to the lakes up to the year 2000. These figures are shown on Figure 17 together with the projected boundary of the Great Lakes "urban" megalopolis area. The man-made heat inputs to Lake Ontario and Lake Erie in 2000 is estimated to amount to about 6 percent of the natural input. These estimates also indicate that Canada and the U.S. are presently putting about 50 times the amount of waste neat in these lakes as is being put in Lake Superior and by the year 2000 this ratio will increase to 600 times.

It is desirable to estimate the effect of this heat addition on the water temperature. Acres[94] and others[26] have calculated the temperature rise on the lakes by using an overly simplistic model which considers the lake a completely mixed body of water into which the heat will be homogeneously distributed. This could never realistically be expected to occur. Instead one can expect the heated effluents to more or less maintain their integrity for a period of time and move with the wind-drifted currents. These currents are primarily along the shorelines. It is in the shallow waters that the principal spawning, nursery and

FIGURE 17



LEGEND

EXTENT OF GREAT LAKES MEGALOPOLIS

Average Man-made Thermal Input in Btu/hour ft^2

Year	Lake Ontario	Lake Erie	Lake Huron	Lake Michigan	Lake Superior
1968	0.093	.126	0.0077	0.046	0.0021
1980	0.274				
2000	1.26	1.20	0.289	0 52	0.022

EXTENT OF GREAT LAKES MEGALOPOLIS AND AVERAGE THERMAL INPUTS TO LAKES

foraging grounds occur for most fishes and many aquatic invertebrates. Thus, the near-shore water temperatures determine the fate of most of the ecosystems in the lake. Further, these are the areas most effected by thermal discharges.

Local shore-heating effects as shown by the thermal plume of the Pickering Station, Figure 18 (also see Figures 7 and 8) are of the main concern, not only with respect to temperature changes by the near-shore currents, but also with respect to circulation which can be directly related to the temperature changes.

Each plume could travel along the shore, and ultimately, with stations averaging 10 to 20 mile spacing on Lake Erie or Ontario, may result in an almost continuous band of warmed water. The effects of the shoreline ecosystems are impossible to predict at this time.

OWRC has recommended that no further heat be added to the Western Basin of Lake Erie. This recognizes that this basin is in ecological difficulty and that further stress is undesirable. Any of the Great Lakes could eventually approach the state of the Western Basin of Lake Erie. It is not possible to estimate the time at which this will occur for any given lake because it depends on all aspects of man's activity around the lake.

Water should be recognized as a renewable resource and as with any other renewable resource, be managed so that the use of it does not effect a significant change. The stress placed on the resource should not exceed its ability to make up the loss. If the heat is to be thrown away and it is not put into the water, then it must go into the air or into some other large heat sink. Can the ecosystems in the atmosphere accommodate

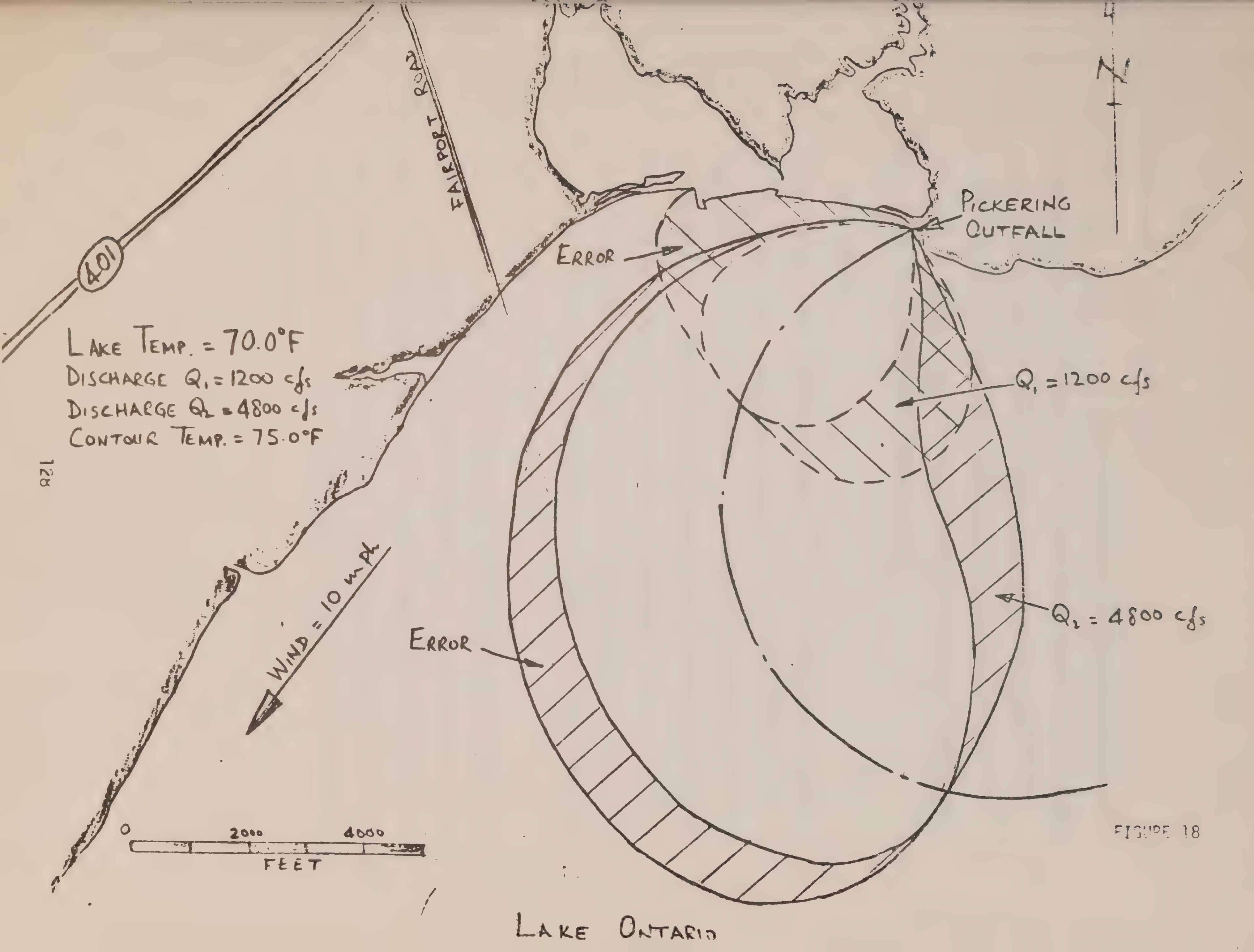

N
PICKERING OUTFALL
FAIRPORT ROAD
401
ERROR
LAKE TEMP. = 70.0°F
DISCHARGE Q1 = 1200 cfs
DISCHARGE Q2 = 4800 cfs
CONTOUR TEMP. = 75.0°F
Q1 = 1200 cfs
Q2 = 4800 cfs
ERROR
WIND = 10 mph
0
2000
4000
FEET
LAKE ONTARIO

FIGURE 18

heat stress a little more easily?

Thus, water quality in the future depends not on extrapolation of present trends, but (1) on the ability of regulatory agencies to formulate suitable guidelines for water-quality preservation and conservation, (2) on the ability of engineers to arrive at innovative solutions to well-known problems, and finally (3) on the willingness of water users of all types to incoprorate these solutions.

(c) LAND QUALITY

As mentioned in the Background Report[95], it is difficult to separate "urban" from "rural" problems, particularly in Southern Ontario. An issue which is especially relevant is the matter of choices as to lands for metropolitan and urban areas, transportation, transmission and communication corridors, land for airports, farmland, forests, land for mineral and aggregates extraction, recreational lands and waters, lands and waters for fish and wildlife habitats, special-interest lands and lands and waters for energy production.

Of all the dominant uses, forest lands appear to have the greatest potential for multiple-use management programmes, eg. timber production, recreation, wildlife habitat, erosion control, water production, etc. Farmlands, forests and recreational land where landscape quality and aesthetic qualities are a consideration in management, also have an important potential in this regard.

Northern Ontario

By 1991 Northern Ontario will maintain its present role as a producer of natural resources at a level not far above that which exists at present. The agricultural industry in the north will ebb still further and will be important only as a local supplier of dairy products and produce for the growth centers. The recreation industry will be at a higher level in 1991 because of the greatly improved access to the north from Southern Ontario and Manitoba and the increases in population.

Southern Ontario

For Southern Ontario the major source of an overview of what can be expected is the publication - "Design for Development: The Toronto-Centered Region"[93]. The Region is both the major economic and financial hub of the Canadian economy and an active contributor to the urban complex, which is commonly termed a megalopolis, that reaches from Montreal to Windsor and southwest to Chicago. This strategic location, in relation to the vitality of North American growth, is a major driving force in shaping the Toronto-Centered Region.

The population in this lake-oriented settlement has grown extremely rapidly; nearly four million people now live within a radius of 90 miles of Toronto. By the year 2000, nearly eight million people - about two-thirds of all of Ontario's population - probably will make this Region their home.

The two-tier arrangement[93] of cities along the entire corridor from Hamilton to Oshawa will give the citizens a wide variety of choice of urban environment. They can decide to live in small cities, medium-size

cities, or in the Metropolitan center. A parkway belt-system within the lakeshore urbanized area will separate the two tiers of cities. This belt system could incorporate the highly efficient transportation facilities, trunk services, electric transmission lines, and other services which will be needed to service this system properly in an integrated way.

A substantial number of manufacturing firms and services, and government facilities could be located as advantageously to the north and east of Toronto as elsewhere. By encouraging such location and stimulating these outlying centers so that they can attract many more residents and commuters, we can reduce the increasing congestion within, and now extending mainly westward from Metropolitan Toronto. At the same time, we shall be laying the basic framework for a carefully planned decentralized urban region of the future and reducing air-and water-quality problems.

Rural Ontario

In rural Ontario in 1991, a great deal of effort will be expended in increasing aesthetic and landscape quality. This is not only by private initiative but also through increased programmes by government bodies, both on public lands and in co-operation with private landowners on private lands. All development, both private and public, will conform to highly developed and soundly based regional land-use plans. Roads and energy transmission corridors will have to meet strict environmental quality standards.

(d) AESTHETIC VALUES

Our knowledge and sense of values have changed significantly and are continuing to change. We are beginning to realize our dependence upon the intricate web of nature, of which we are part. If we are to be concerned about the quality of life, we must give attention to the quality of our man-made environment.

In the planning and construction of a power system, environmental protection and maximum economy are not entirely compatible. While environmental effects cannot be wholly eliminated, they can be minimized by care in design, construction and operation. Aesthetic values should be taken into account by careful siting and design.

With the continuing trend towards very large steam-electric generating stations combined with the public demand that power stations be located outside urban areas, then the increased use of transmission lines is a foregone conclusion. On the other hand, a public outcry is beginning about the aesthetic depreciation of the environment caused by large unsightly transmission towers. Lesser effects include interference with the reception of radio and television signals.

In addition to the transmission lines associated with power generation facilities,the erection of cooling towers 500 ft. high and stacks 1000 ft. high will also tend to destroy the aesthetic value of the landscape.

Loss of enjoyment of recreational facilities due to pollution-caused problems cannot be measured in pure financial terms, yet somehow it must be considered in the value of life.

Summarizing, in past energy developments, too little attention has been paid to their effects upon aesthetics, to the detriment of the quality of life. In future, some consideration should be given to these values when planning future energy developments, but it may be necessary to trade one environmental condition against another. Education of the public in these matters and in the consequences of all the alternatives will aid in arriving at the right solutions.

(e) FUTURE TECHNICAL DEVELOPMENTS

Other energy sources may come into existence over the next twenty years and certainly beyond. The purpose here is to indicate briefly the environmental impact of these developments rather than their technical or economic feasibility. Additional details of these methods may be obtained from a series of papers in Reference 97. All of the proposed methods require extensive research and development before their relative usefulness can be determined. The relative expenditure of money on research and development in the U.S. is of some interest and is listed below:

$30 million per year on nuclear fusion,
$420 million per year on nuclear fission,
less than $1 million per year on solar energy,
$20 million per year on fuel cells,
$2 million per year on magnetohydrodynamics,
and more than $30 million per year on coal gasification.

Magnetohydrodynamics (MHD)

MHD power generation relies upon the high-velocity flow of a conducting fluid through a transverse magnetic field. Either, hot ionized-gases or

a liquid metal, can be used with generators operating at temperatures of 3500 - 5000^{0}F and they would produce electrical power from fossil fuels at efficiencies of up to 60%. It is being considered as a topping unit on a conventional steam plant.

Easily ionized substances are added as seeding material to the combustion gases to increase their electrical conductivity.

With the use of a non-sulfur potassium seed, complete elimination of SO_2 emissions is possible. At 0.9 g-mole K_2CO_3/kg coal, 99% removal of SO_2 was obtained in the combustion of a 2.2% sulfur coal. Regeneration of the spent seed is accomplished by heating with a H_2+H_2O mixture at 1530^{0}F. Thermal pollution is less in the MHD plant compared with the nuclear plant. A first-generation MHD plant with an efficiency of 52% produces only 43% of the waste heat of a nuclear plant.

A number of difficult equipment problems have to be solved before MHD systems could be escalated to full commerical size.

(a) The extremely high reactor temperatures require special heat-resistant materials and special heat-exchanger design.

(b) Corrosion problems caused by the seeding material will be severe.

(c) The high operating temperatures of the MHD system may create large quantities of NO_x in the exhaust gases.

Development of MHD units up to 40 MW (in Russia) has been pursued in several countries. The effort in North America is at a low ebb at the present.

Fuel Cells

Fuel cells, in which chemical energy is converted directly into electricity, are virtually non-polluting systems for the generation of electricity, at efficiencies of 50 - 60% compared to the normal thermal generating station efficiencies of 30 - 40%.

However, before fuel cells can become a major electrical power source, a number of critical problems would have to be overcome.

(1) Because of their small size, their sensitivity, and the large maintenance requirements, they do not, at present, lend themselves to the construction of large-size electrical generating units.

(2) Since the best fuel is hydrogen, the large-scale fuel cell must be located with pipeline connections to commercial hydrogen manufacturing facilities.

(3) To date, fuel cells have not been able to operate trouble-free for long periods of time, and their cost is high.

It is believed that they offer a good future potential for Northern Ontario, because they will provide a small impact on the fragile ecology of that region and power will be required in widely separate regions.

Breeder Reactors

The breeder reactor is based on the principle that certain atoms become fissionable after they have reacted with neutrons. There are two atoms of this type; uranium-238, which on reacting with a neutron becomes fissionable plutonium-239 and thorium-232, which becomes fissionable

uranium-233. The breeder reaction will make available for use the entire world supply of uranium-238 and thorium-232, with an energy equivalent of several thousand times that of the initial world supply of fossil fuels.

Several types of breeders are being developed: (1) using liquid sodium as coolant, (2) using helium gas at high pressure as coolant, and (3) using molten salt as coolant. In the first two types the reactor chamber will be hermetically sealed (water and air must be excluded from the chamber containing sodium). Experimental breeders have been in operation since 1963 and the first commercial breeder power plant (1000 megawatt capacity) is planned to be in operation in 1984.

Current fission reactors and future breeder reactors will produce approximately the same types of fission products which will have to be dealt with, however the breeders will contain much greater quantities of radioactive materials at one time. As a result their development is being opposed by some groups particularly in the United States. Some of the hazards of breeder reactors are listed below:

(1) Higher core temperatures result in higher probability of melt-down of fuel rods with resulting criticality.

(2) Liquid sodium becomes highly radioactive due to neutron bombardment. When replacement of sodium is necessary, this represents a special disposal problem because of the large volume of contaminated material with hazardous chemical properties.

(3) In the event of rupture of the heat transfer systems, the liquid sodium would react explosively with the water.

(4) Fast breeders will contain large quantities of plutonium which has a lower critical mass (13 lbs.) than uranium-235 (20 lbs.) and accidental failure could result in nuclear explosion, although the chance is remote.

Fusion Reactors

Fusion reactions based on the use of Deuterium (D_2) may eventually become a major source of electrical power on a long-term basis because there is an almost inexhaustible source of deuterium in sea water. In addition, this type of reaction produces only non-polluting and non-radioactive gases, with a very small amount of disposable wastes along with electrical energy conversion efficiencies of 90%. From an environmental standpoint this method of generating power is highly desirable because;

(1) There are no radioactive waste products to process or store.

(2) There is no danger of nuclear explosion. Any failure in the system containing the plasma will result in immediate quenching of the reaction since it cannot occur under ordinary conditions.

(3) In the event of failure, the total release of radioactive materials would be very small. The only radionuclide released would be tritium of which there would be only 10 kgm in the reactor at one time.

(4) There is the possibility of converting plasma energy directly into electrical energy, thereby eliminating the problem of waste heat.

The chief environmental problem expected to arise from fusion reactors is the escape of tritium during operation. The possible extent of this re-

lease is not known at present. However, the reactions occur only at temperatures of 100 million to 500 million degrees K, temperatures at which any mechanical container would be vaporized. The difficult task presently under development is to devise magnetic bottles in which to contain these reactions. Estimates vary greatly as to the time when controlled fusion may be achieved.

Solar Power

Direct conversion of sunlight is an environmentally ideal power source. The possible use of solar energy for the generation of electrical power has three alternative methods which could be considered[96].

(1) Transmission of power, collected in space by means of a satellite system via microwave to a receiving system located on earth.

(2) The collection of energy on the surface of the land by solar cells or storage media with its conversion to electrical power.

(3) The location of a floating power station in warm ocean waters, which would be used for power generation.

It would appear that none of the above methods could be developed commercially on a large-scale before the next century.

Section VI

PROJECTED LONGER RANGE PROBLEMS

(a) POSSIBLE GLOBAL CLIMATE CHANGES

In attempting to predict any long-range environmental problems, the lack of quantitative and predictive research in this field leads to a large amount of uncertainty about future conditions. There are primarily three areas, where possible climatic changes could occur, which are being discussed and debated at present.

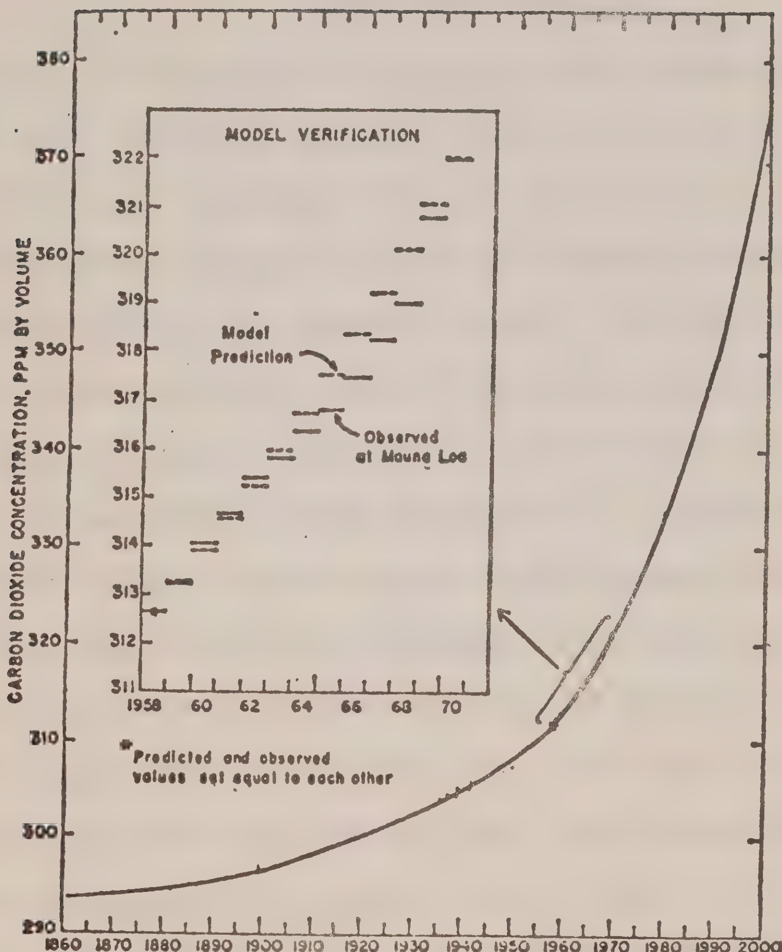
Carbon Dioxide Build-up

Carbon dioxide is one of the products of combustion of fossil fuels. Over the last few decades the average concentration of CO_2 in the atmosphere has increased at the rate of 0.2% per year[10]. Estimates of the increase of CO_2 in the atmosphere have been made by Machta[98] and are shown in Figure 19. The steep rise is due to man's steadily increasing use of combustion.

Carbon dioxide will effectively transmit the ultra-violet radiation from the sun but will selectively absorb the longer wavelength radiation from the earth. Consequently, as the atmospheric CO_2 concentration increases, the earth will tend to become warmer.

It has been estimated[12], that an increase in the carbon dioxide concentration from 320 to 375 ppm as indicated by Machta's estimates will occur by 2000 and will warm the surface layer of the earth by about $1^{o}F$. While this change is unlikely to be critical, it is apparent that a continuation of CO_2 production would lead to large increases in the CO_2 concentration. Manabe and Wetherald[12] suggest that a doubling of the concentration of

FIGURE 19



Model calculation of atmospheric CO_2 from combustion of fossil fuels.

the gas could lead to a $5^{0}F$ increase in world temperature which "could trigger other warming mechanisms and possibly lead to irreversible effects." The consequences of such an event are so great that it should not be dismissed from our planning even though it may be a century or more in the future.

Waste-Heat Production

The amount of heat input into the environment depends directly upon the energy used. Heat will always be produced and as power generation moves from fossil fuels to nuclear fuels the quantities will increase. In addition, heat is released into the environment from industrial, transportation, domestic and commercial sources. The 4000 square miles of the Los Angeles basin now generate in thermal power, the equivalent of more than 5 percent of the solar energy absorbed at the ground and this amount is expected to rise to 18% by 2000[99]. Individual cities,with their high level of energy use,have higher downtown temperatures (see Table III) and are covered by overhead three-dimensional heat islands, which act as chimneys to expel pollutants (Figure 2). Both the "useful" and the "waste" energy eventually finds itself heating the environment and one major study concludes that they "see the possibility of climatically significant changes on a regional scale in the near future" and that "on a local scale, this influence is already very large"[100].

Probably the most significant and far-reaching effects of our continuing rate of growth production will be on a global scale. According to the report of the Study of Man's Impact on Climate[12] -- "there is a distinct

possibility (according to some, a probability) that a temperature rise associated with the anticipated injections of heat and CO_2 into the atmosphere in the next century would result in melting of Arctic ice". The reduction in the earth's surface reflectivity could cause more heat to be absorbed with a consequent acceleration of the process. In addition there may be large changes in precipitation, wind systems and ocean currents, which could create deserts in formerly productive areas and have other serious biological and social consequences.

Turbidity

It has been estimated that between 5 and 45 percent of the particulate matter in the atmosphere is produced by man[101]. Much of the man-made particulate is directly emitted during combustion or else is the product of gases produced from the industrial and domestic consumption of fuel, the internal combustion engine, the incineration of domestic waste and agricultural burning. Other particles are emitted during some industrial and mining processes and indirectly from some food production practices, such as ploughing and overgrazing of arid or semi-arid lands.

Particulate matter in the atmosphere may cause several dramatic implications, such as scattering of sunlight, preventing it from reaching the earth's surface, affecting the formation of clouds, snow and rain, thus changing the precipitation and temperature balance of the earth. The consensus opinion is that this will produce a cooling of the earth and some claim it will balance the effects mentioned above.

Summary

It is most unfortunate that more information is not available on the long-run environmental effects, for policy makers are faced with the problem of making decisions under conditions of uncertainty, both with respect to the absolute necessity of making a very major change and with respect to the time at which this change must be made. However, it is unreal to assume that we will be able, some time in the future, to balance global warming trends (CO_2 increases waste heat disposal) by cooling trends (increased turbidity) and maintain the earth's natural thermal balance. It is not too early to recognize these possibilities and to promote additional work directed toward a better understanding of man's impact on the climate.

(b) PREDICTED CONSEQUENCES OF EXPONENTIAL GROWTH

Many studies have demonstrated that nearly all of man's activies (population, power generation, industrial growth, transportation growth, food production, use of resources, production of waste products, to name a few) grow in an exponential way. This is, they double time and time again every few years. This growth has not created serious problems in the past because the limits of the earth's capacity to sustain the growth have not yet been reached. However, there is growing concern that certain limits are now being approached and we must soon face the reality of living in a closed system. It is imperative to look ahead and try to predict what sort of crises may occur and then try to devise means of avoiding them. This is a task fraught with uncertainties arising from lack of knowledge of our complex system and the unpredictable reactions of humanity toward change.

Various growth predictive models have been devised in the past. Most of them have underpredicted what actually occurred because they were based on near-linear projections. Quite recently, Forrester at M.I.T. has devised a very comprehensive computer model which attempts to account for the interaction of many complex inter-relationships influencing world-wide growth[102]. It is probably the most ambitious attempt at predicting the future undertaken to date.

Previously Forrester has modelled several other complex processes and his computer modelling of urban dynamics[103] is particularly well-regarded by urban planners and is currently influencing urban planning. Consequently, his new effort in predicting man's future in a much broader sense in <u>World Dynamics</u>[102] is being widely discussed and debated. His complex computer model yields an overall prediction of the course of world events.

In analyzing the world system, he considers 5 parameters (1) population, (2) capital investment, (3) natural resources, (4) capital devoted to agriculture and (5) pollution. These parameters are considered as parts of "feed-back" mechanisms. The influence of 52 separate factors and their inter-dependance are taken into account. Only the pollution aspects of this model are considered here in any detail. The pollution subsystem is shown in Figure 20. Population and capital investment influence pollution levels by acting on the rate of pollution generation. The rate of pollution generation is assumed to increase linearly with respect to increasing population. Increased capital investment increases pollution generation through increased power generation, increased processing of raw materials increased industrial wastes, increased use of fertilizers and chemicals in

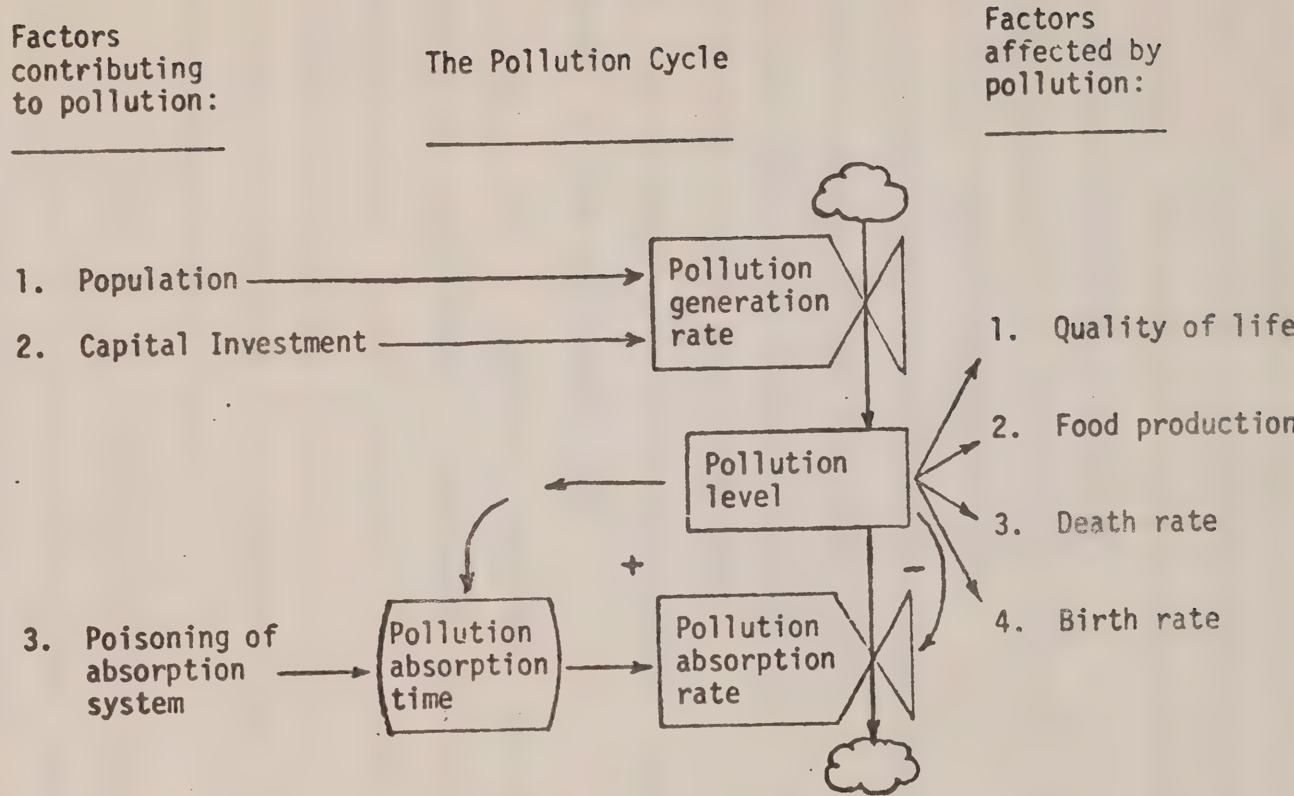


Figure 20 The Pollution System According to Forrester (102)

agriculture, and by several other factors.

The ways in which all of the factors, considered, actually influence pollution is not known. Consequently, Forrester makes broad assumptions about these influences which are currently being questioned, debated and investigated. For example, he assumed graphic relationships from which the following observations are drawn:

(1) Pollution-generation rate is considered to increase 8 fold when capital investment increases 5 fold.

(2) Food production, decreases to 50% of the present level if pollution increases 25 times the present level.

(3) Death rate increases to 10 times the present rate if pollution increases 60 times the present level.

(4) Birth rate decreases to 50% of the present rate if pollution increases 25 times the present level.

All of these assumptions may be immediately questioned. He bases them on observations of the general trends. Consequently, the levels and time estimates predicted by Forrester are probably not accurate. At this time, one should only consider the main thrust of his work, and the trends his model predicts rather than be concerned about what particular decade a certain trend may develop.

Many important mineral resources are rapidly approaching depletion. Table XVII gives the numbers of years for which the known reserves will last at the 1970 usage rate and at the continued exponential rise in usage rate[104].

TABLE XVII

Depletion Times for Mineral Resources

Metal	Time to Deplete Reserve at 1970 Rate of Usage (Years)	Time to Deplete Reserve if 2.5% Increase in Usage Rate Continues
Mercury	14	13
Lead	18	15
Platinum	19	16
Gold	19	16
Zinc	20	17
Silver	23	18
Tin	25	19
Copper	40	28
Tungsten	45	31
Molybdenum	100	51
Nickel	130	59
Aluminium	160	65
Cobalt	160	65
Manganese	160	65
Iron	400	98
Chromium	560	110

According to Forrester's model, when our present-day system is projected into the future without any changes, depletion of natural resources is found to be the growth-limiting factor (see Figure 21). Population reaches a maximum and declines slowly in the next century. Pollution increases to several times its present level but does not limit growth. Table XVII suggests that we may indeed be on the path depicted in Figure 21.

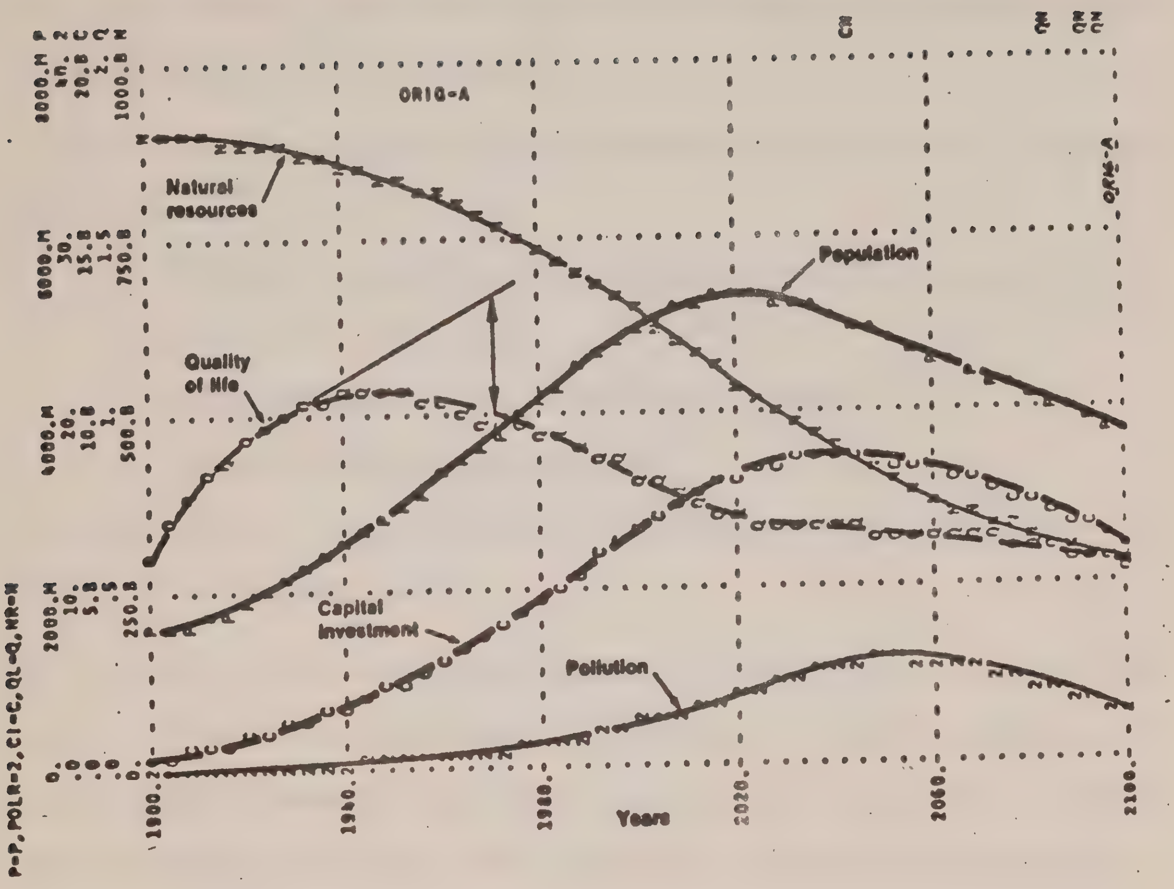


FIGURE 21 World system projected into the future under present conditions.

If technology finds ways to reduce the usage rate of natural resources through the wider use of plastics or by recycling, the computer model predicts that pollution emerges as the limiting factor (Figure 22). In this case, however, the turning point is followed by catastrophic decline in population in the next century.

In a similar way a number of other strategies for the future, are often discussed,

(a) continued economic growth (increased capital investment)

(b) reducing the birth rate

(c) technological solution to pollution problems

(d) increased global food production

all give rise to a "pollution crisis" similar to that depicted in Figure 22 in the next century.

It is interesting to note, that attempting to solve the pollution crisis shown in Figure 22 by application of technology to reduce pollution generation, still produced a pollution crisis but at a later date. In this case, increased industrial growth ultimately outpaced pollution control. As a result more people suffered the ultimate consequence.

All of the catastrophic changes predicted by Forrester's model result from rapid pollution increases at some point in time. The assumption made about the influence of pollution may unrealistically weight this factor too strongly. Considerably more thought and research of his assumptions and the formulation of more accurate ones is clearly warranted. Because his present calculations illustrate that pollution is a powerful

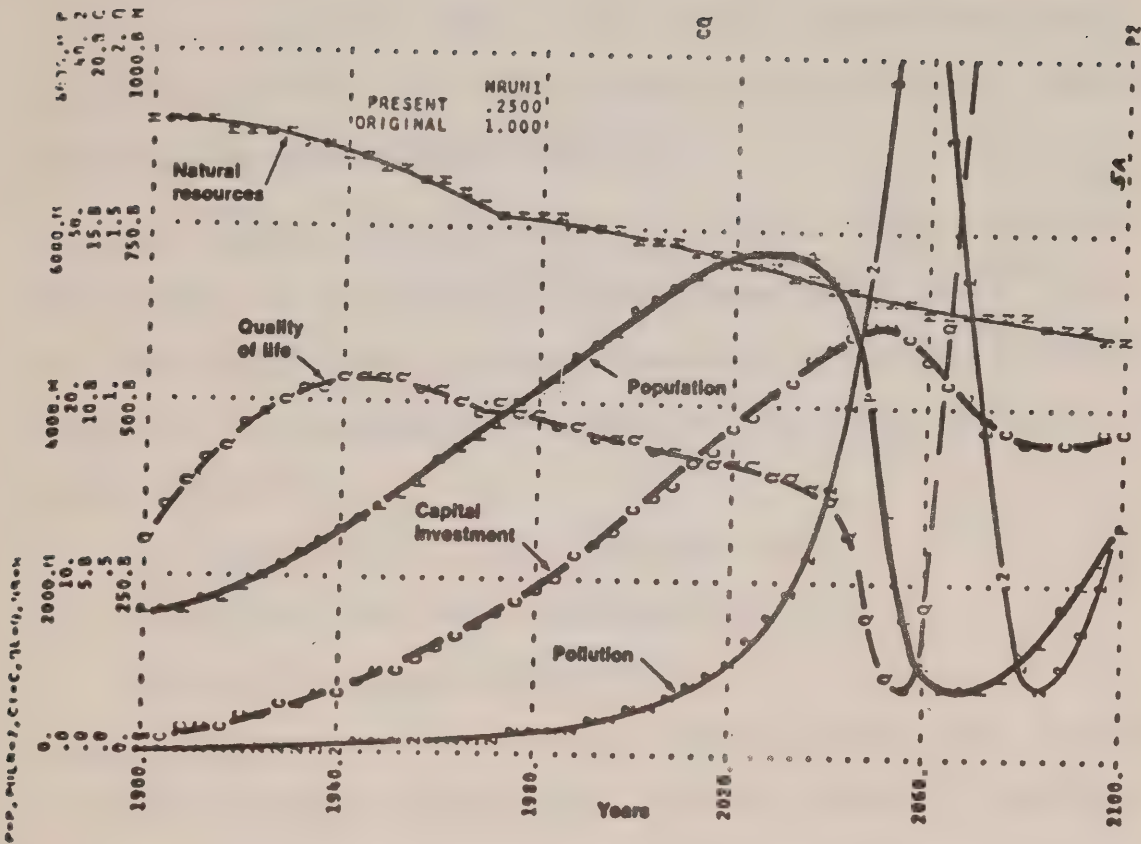


FIGURE 22 Pollution crisis results when natural resource usage rate decreased 75% in 1970.

triggering influence, the pollution subsystem in his model deserves immediate attention. Moreover, prevention of a pollution crisis involves control of many factors besides those directly related to the environment.

Only when an unrealistic model, in which it was assumed that natural resources are infinite and pollution does not exist, did over population emerge as the growth-limiting factor.

Forrester has also employed his computer model to suggest strategies for avoiding the fates shown in Figures 21 and 22. To date[105] he has been able to produce a kind of steady-state system only by making relatively drastic changes in his input starting in the year 1970. The changes needed were:

(a) natural resource usage rate reduced 75%

(b) pollution generation rate reduced 50%

(c) capital investment reduced 40%.

These changes resulted in a decreased food availability and a decreased birth rate, thereby inducing stability through hardship. They result in a type of "zero-growth" society shown in Figure 23. The concept of zero growth has also been described in detail in another study conducted for the Advisory Committee for Energy[106].

Obviously the changes described above would be difficult to institute and in fact, since they represent imposed hardships, they may not be justifiable. The growth-oriented business world would resist even relatively minor reductions in capital investment and resource usage, let alone the staggering values required by Forrester's computer model.

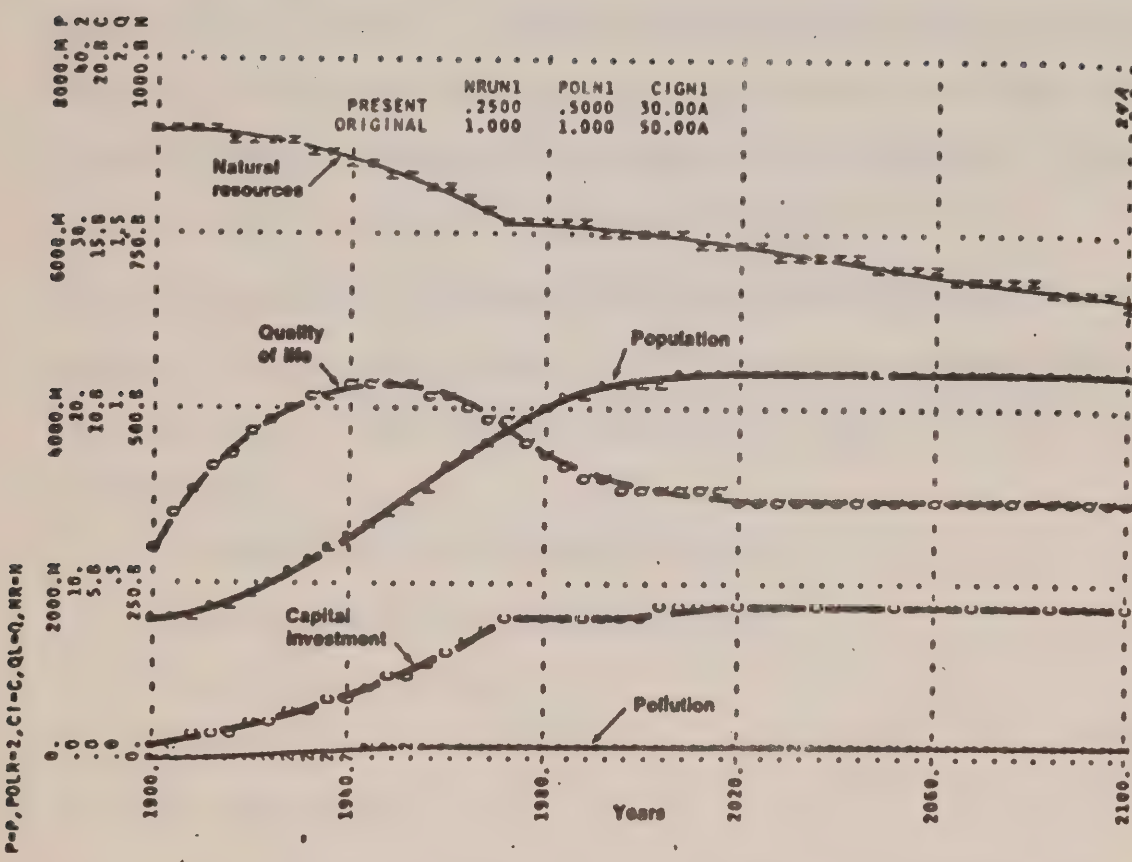


FIGURE 23 Steady state induced by reducing natural resource usage rate 75%, pollution generation rate 50%, and capital investment 40% in 1970.

It is not possible to single out the impact of the electrical power generation industry on this long-range and broad-based analysis, but it has a strong impact on future growth. The consumption of energy resources is not likely to be an ultimate limiting factor for growth, because of the essentially unlimited supply of energy available from nuclear sources. There is evidence that there may be a period of energy shortage in the next two decades during the conversion from fossil fuels to atomic sources. However, the shortage will be alleviated if breeder reactors come into successful operation in 1985 as expected.

The crisis predicted by Forrester, which will result from continued exponential growth, can be avoided only by arriving at a steady state in the world system. Three basic actions will be required to move toward a steady state:

(1) Reduce usage rate of natural resources

(2) Reduce and redirect capital investment

(3) Decrease birth rate.

Many difficulties can be anticipated in changing from a policy of growth to one of steady-state.

However, the first two actions may be controlled by controlling the availability of electrical power, if or when it becomes evident that we must proceed in this direction.

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